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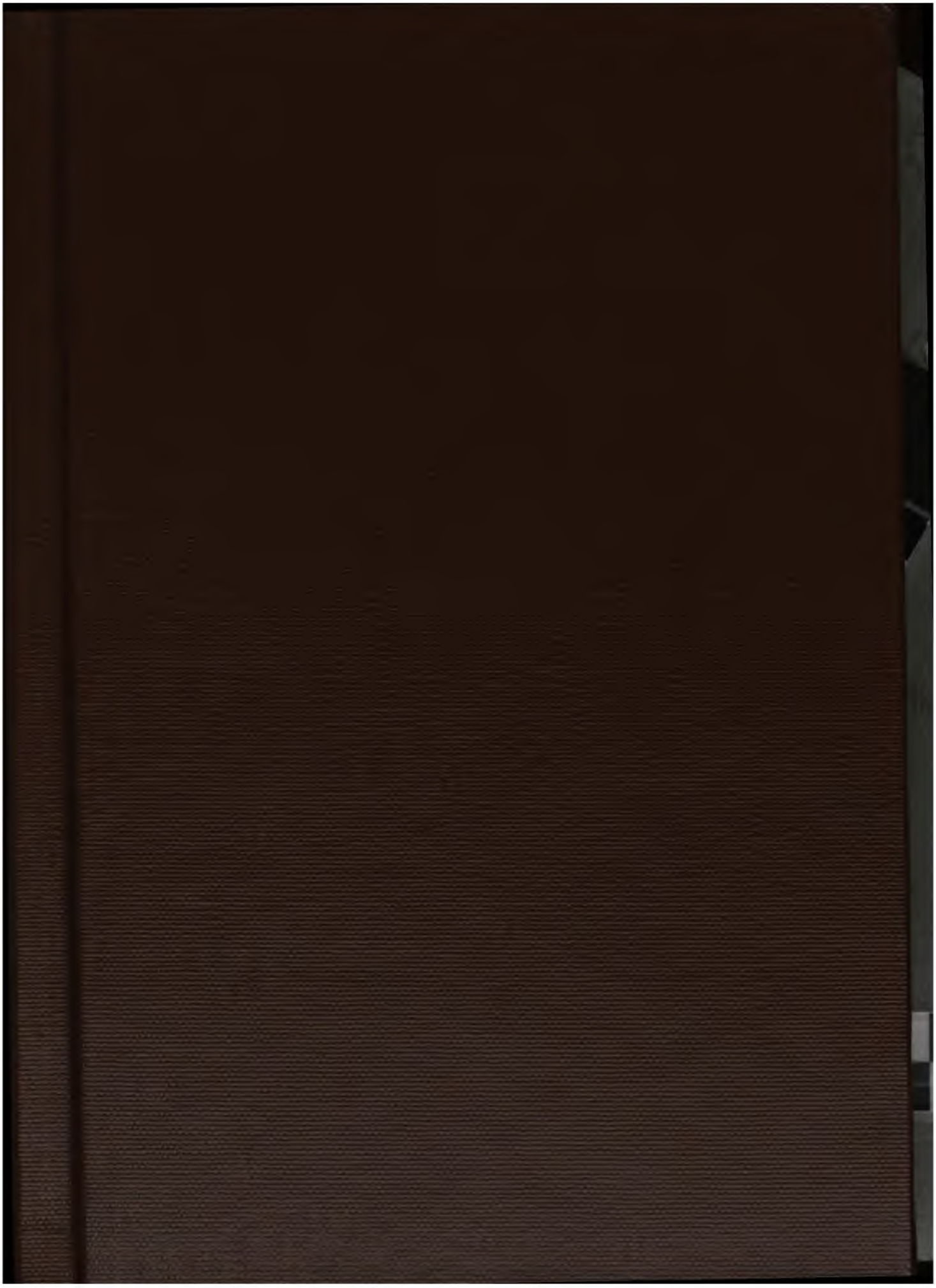

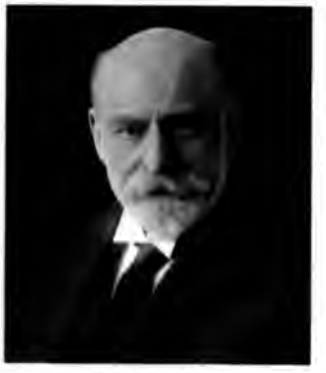

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Part 1.—Annual report for 1870. Enquiry into an alleged discovery of coal near Umrit, and of the indications of coal in the Cuddapah district. Mineral statistics of the Kumaon division.

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Part 3.—The progress and results of borings for coal in the Godavari valley near Dumagoodem and Bheemaveram. On the Narbada coal-basin. Hints on the geology of the Central Provinces. Additional note on the plant-bearing sandstones of the Godavari valley.

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THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1904. [July.

THE UPPER PALÆOZOIC FORMATIONS OF EURASIA.

By TH. TSCHERNYSCHEW, *Director of the Russian Geological Committee.*[1] *Translated by* PROFESSOR P. BRÜHL, *Civil Engineering College, Sibpur.*

We commence our summary of the Upper Palæozoic formations with the eastern slope of the Ural. The most comprehensive information about the nature of the Carboniferous sediments of this region we owe to A. Karpinsky, who has published not only a geological map of the Asiatic side of the said mountain range, but also a series of preliminary reports on the scientific results of his many excursions into the Ural Mountains. On the basis of these published data, and of the additional information extracted from the yet unpublished complete geological description of the eastern flanks of the Ural Mountains and kindly supplied to me by the above-mentioned scientist, we are able to draw up the following scheme of the structural features of the respective Carboniferous sediments.

The base of the Carboniferous sediments is formed by shales, argillaceous slates, sandstones, and conglomerates, which enclose beds of coal and concretions of clay-ironstone, and which, at their lower horizons pass insensibly into sandstones and slates of Devonian age. Organic remains are almost exclusively represented by plants, *Lepidodendron Glinkanum*, Eichw., *Stigmaria ficoides*, Brongn., etc.

1 Forming pages 709—733, 740—742 of a monograph entitled "The Upper Carboniferous Brachiopods of the Ural and Timan Mountains," Mem. du Comité Géologique, vol. XVI, No. 2. St. Petersburgh, 1902.

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Part 2. (out of print)—On the goldfields of south-east Wynaad Madras Presidency. Geological notes on the Sabarmati hills in the Upper Punjab. On water-bearing strata of the Surat district. Sketch of the geology of Nicobar's territories.

Part 3.—The Khargon coal-field, with notice of coal explorations in the Narbada region. Note on coal recently found near Mallang, Khasia Hills.

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Part 2.—The settlement of Dr. Oldham. On the age of some fossil floras in India. Description of a crinoid of Stapelia Grimm, with notes on the sub-genus and allied forms. Note upon the Sub-Himalayan series in the Dehra (Dun-coal) Hills.

Part 3.—On the Age of some fossil floras in India. On the geological age of certain groups comprised in the Gondwana series of India and on the evidence they afford of distinct zoological and botanical terrestrial regions in ancient epochs. On the relations of the fossiliferous strata at Mysore and Kota, near Chanda in C. P. On the fossil mammalian beasts of India and Burma.

Part 4.—On the age of some fossil floras in India. On the osteology of Merycopotamus dissimilis. Additions and Corrigenda to paper on tertiary mammalia. Occurrence of Hexaxonia in India. On the geology of the Fir Panjal and neighbouring districts.

Vol. X, 1877

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Part 2.—On the rocks of the Lower Godavari. On the 'Afgoi Sandstones' near Berbera. On fossil floras in India. Notices of new or rare minerals from the Shevaroy. On the Arvali series in Northwestern Rajputana. Borings for coal in India. On the geology of India.

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Vol. XI, 1878

Part 1.—Annual report for 1877. On the geology of the Upper Godavari basin, between the rivers Wardha and the Godavari near the civil station of Sironcha. On the geology of Kashmir, Kishtwar, and Pangi. Notices of Siwalik mammals. The palæontological relations of the Gondwana system. On 'Remarks, &c., by Mr Theobald upon crystics in the Punjab.'

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NOTE.

The map forming plate 18, showing the position of the Trias in Baluchistan, referred to in Mr. Vredenburg's paper on *Halorites*, will be issued with Part 4 of this volume.—DIR., G. S. I.

additional information extracted from the yet unpublished complete geological description of the eastern flanks of the Ural Mountains and kindly supplied to me by the above-mentioned scientist, we are able to draw up the following scheme of the structural features of the respective Carboniferous sediments.

The base of the Carboniferous sediments is formed by shales, argillaceous slates, sandstones, and conglomerates, which enclose beds of coal and concretions of clay-ironstone, and which, at their lower horizons pass insensibly into sandstones and slates of Devonian age. Organic remains are almost exclusively represented by plants, *Lepidodendron Glinkanum*, Eichw., *Stigmaria ficoides*, Brongn., etc.

[1] Forming pages 709—733, 740—742 of a monograph entitled "The Upper Carboniferous Brachiopods of the Ural and Timan Mountains," Mem. du Comité Géologique, vol. XVI, No. 2. St. Petersburgh, 1902.

The strata just referred to are overlaid by limestones with valves of *Productus giganteus*, Mart., and *Pr. striatus*, Fisch., and prominent coral banks. Here and there these undoubted Lower Carboniferous limestones are covered by others, which differ considerably from them palæontologically, and which in all probability belong to the middle division of the Carboniferous system. The same age is probably correctly ascribed to the palæontologically well-characterized Goniatite beds of Schartymka.

In most cases these limestones are overlaid by calcareous shales and calcareous sandstones, which enclose valves of *Spirifer mosquensis*, Fisch., in association with forms (gastropods and brachiopods) which remind one forcibly of corresponding forms from the middle division of the Carboniferous strata of the Donez basin. The uppermost beds of the Carboniferous system, as developed on the eastern slopes of the Ural Mountains, consist of white or yellow tripoli-like rocks, of marls, sandstones, clays, and gypsum, which very distinctly mark the boundaries of the Carboniferous sea-basin just before its complete disappearance.

As pointed out by A. Karpinsky,[1] an interesting complication in the architectonic features of the Carboniferous sediments may be observed at the eastern side of the Ural Mountains. The limestones of Lower Carboniferous age (with *Productus giganteus*) are succeeded immediately by rather thick conglomerates and breccias, which enclose frequently fragments of the underlying limestone with *Productus giganteus*, but which in other localities are of a more varied composition, without the former limestones losing their preponderance. Fragments of one decimeter in diameter to the size of a human head, sometimes even from 0·6 to 1 meter across, are frequent. The interstices between the larger pieces are filled with smaller fragments, and the whole is cemented together by a compact argillaceous calcareous matrix, which reminds one of a hardened calcareous mud. According to the statement of A. Karpinsky, the fragments are either rounded or entirely angular. In most cases not a trace of stratification is observable in the matrix of these conglomerates and breccias, provided one does not mistake the cracks traversing the blocks of rock for such. Above the conglomerates are found sandstones, marls, and argillaceous limestones, which here and there contain thick accumulations of masses

[1] Bull. Com. Géol., T. VIII, S. 204—206; Guide des exc. du VII. Congr. Géol. Intern., V, p. 12.

of corals (according to A. Stuckenberg's determination *Chætetes radians*, Fisch., *Syringopora parallela*, Fisch.). Although these conglomerates, as mentioned above, are not developed in all localities, and may be even wanting, in consequence of which there rest, immediately on the lower and partly on the middle limestones, rocks which in other places overlie the conglomerates, their mere existence, and the occurrence of numerous fragments with *Productus giganteus*, point to the fact that during the Middle Carboniferous epoch continental conditions obtained on the eastern flanks of the Ural Mountains, if not generally, at least locally. The origin of the conglomerates, possibly glacial like those of the Talchir group or the corresponding formations in Australia, is a question which for the present must remain in abeyance.

After a second visit to the banks of the Bagarjak, where the most instructive exposures of the conglomerate are found between the villages of Osmanowa and Kosakowa, A. Karpinsky expresses himself rather cautiously, but he is inclined to acknowledge the glacial origin of the conglomerate. Although the boulders show no instances of polishing and striation which could not be ascribed to tectonic changes (dislocations or faulting on a smaller scale), the absence of stratification, of signs of a sorting of the constituents, and the probable contemporaneity of their formation with Carboniferous glacial deposits of other countries speak nevertheless, according to the views of that scientist, rather for a glacial origin of the conglomerates.

East of the Ural Mountains we meet with two extensive spreads of Carboniferous deposits, in the Kirgise Steppes and in the basin of Kusnezk. According to the latest results of the geologists who took part in the surveys carried out along the Siberian railway, as well as of the scientists who shared in the labours of the geological section of the Cabinet of His Imperial Majesty the Emperor of Russia, the composition of the Carboniferous sediments of the Kirgise Steppes resembles that of the basin of Kusnezk very closely. In both cases there occur, at their base, limestones with a Lower Carboniferous marine fauna, which in its essential features is very similar in the two areas, but which differs considerably[1] from the contemporaneous fauna found on the eastern slopes of the Ural Mountains.

[1] *Syringothyris cuspidata*, Mart., and *Spirifer tornacensis*, de Kon., which are characteristic of the deposits in the Kirgise Steppes and the basin of Kusnezk, are total strangers to the fauna of the eastern slopes of the Ural Mountains. *Productus giganteus*, Mart., which is common here, is nearly entirely absent from the Lower Carboniferous deposits of the Kirgise-Steppes and the Altai.

All those observers who have been working in both the areas referred to have invariably come to the conclusion that there is no break between the above-mentioned limestones and the overlying productive series, and they adduce a number of facts which bear testimony to the gradual displacement of the marine Lower Carboniferous sediments by argillaceous and arenaceous deposits interstratified with beds of coal.

But with regard to the age of the productive deposits, or rather in the determination of the chronological limits within which they have to be disposed, opinions differ considerably. This divergence of opinion exists chiefly with reference to the basin of Kusnezk, since with respect to the age of the coal-beds of the Kirgise-Steppes A. Krasnopolsky, N. Wyssozky and A. Meister have, after the detailed investigations carried out between 1894 and 1896, arrived unanimously at the conviction that it is impossible to see in the coal-bearing series sediments younger than Carboniferous. With reference, however, to the basin of Kusnezk, most geologists who have had the opportunity of acquiring an intimate acquaintance with the coal-bearing strata of that region ascribe to them an age not more recent than Carboniferous. But of the palæophytologists who have studied the flora buried in these strata, some (Geinitz and Grand-Eury) consider it to be an equivalent of the productive series of Western Europe, others (Schmalhausen, Kosmowsky) ascribe to it a Mesozoic (Jurassic) age or place it within the limits formed by the Permian and Jurassic systems. The most detailed analysis of the available information concerning the age of the flora of the coal-bearing strata of Kusnezk is due to Zeiller,[1] who, after having studied the papers of Schmalhausen,[2] has arrived at some important results. Of interest to us among these results is the demonstration of the peculiar features of the flora of Kusnezk, which, like the one discovered by Bodenbender and Kurtz in Argentina, is a mixture of European forms with representatives of the Glossopteris-flora of India. According to Zeiller, this peculiar feature can be explained only on the hypothesis that the basin of Kusnezk, similarly to the Argentinian provinces of

[1] R. Zeiller, Remarques sur la flore fossile d'Altai. Bull. Soc. Géol. de France, 3. Sér., T. XXIV., p. 446—487.

[2] J. Schmalhausen, Beiträge zur Jura-Flora Russlands. Mém. Ac. Imp. des Sc. de St. Pétersbourg. 7 Sér., T. XXVII, No. 4 (1879). J. Schmalhausen, Die Jura-Flora des Basins von Kusnezk und des Petschora-Landes. Verhandl. d. Kais. Min. Ges., 2 Serie, T. XVI (1881)—S. 97—178 (russ.).

San Luis and La Rioja as well as the province of Rio Grande do Sul in Brazil,[1] constituted an intermediate region between two distinct botanical provinces. In his paper Zeiller also touches upon the age of the strata of Oranez on the Petschora, from where Schmalhausen has described the *Rhipidopsis ginkgoides*, which Kurtz has discovered also in Argentina, and Schmalhausen declares that species to be of Permian age, which approximately harmonizes with the fact well-known to Russian geologists that the beds of Oranez belong to the Artinskian stage. Similarly does the previously mentioned author ascribe a Permian age to the flora of the coal-bearing series of the Kusnezk basin, although he does not consider its identity with the flora of the Petschora, which is assumed by Schmalhausen, to be proved. On the whole Zeiller proceeds with great caution, and is of opinion that a final solution of the problem is quite possible, provided not only that the collection of fossils is continued, but that the detailed stratigraphical study of the coal-bearing strata is not neglected. This author has already been able to make use of an interesting find, which has been made by P. Wenjukow[2] in the shales which accompany the coal-beds of Koltschugin and which consists of some species of pelecypods and ostracods, of which W. Amalizky has determined *Posidonomya Becheri*, Brown, and *Carbonicola carbonaria*, Goldf. No less remarkable are the discoveries made by I. Tolmatschew on the river Tersja, among which Jones[3] has distinguished six pelecypods (*Anthracomya minima*, Ludw., *A. lævis*, Dawson, var., *A. valencinnensis*, Eth., *Posidonomya subovata*, n. sp., *P. concinna*, n. sp.) and a representative of the ostracods (*Beyrichia Kirbyana*, n. sp.). Jones does not doubt the Carboniferous age of this fauna, and even questions the propriety of ascribing it to the *upper* division of the productive series. These finds lead us back to our original view concerning the age of the coal-bearing beds of the basin of Kusnezk, and on the basis of numerous observations made by the geologists who have been working in that area, they force us to consider the continental deposits

[1] Compare M. R. Zeiller, Note sur la flore fossile des gisements houillers de Rio Grande do Sul. Bull. Soc. Géol. de France, 3 Sér., T. XXIII, p. 601—629.

[2] P. Wenjukow, Geol. Unters. in der nördl. Partie d. Bas. v. Kusnezk im Sommer, 1894. Travaux de la Sect. Géol. du Cab. de Sa Maj., T. I, liv. 2, p. 86.

[3] R. Jones, On some carbonif. shale from Siberia. Geol. Mag., Dec. IV, vol. VIII, p. 433—436.

of that region as forming an uninterrupted series, whose development had, in all probability, been carried to an end before the deposition of the Artinskian strata of the Ural (inclusive of those of Oranez, on the Petschora). If we apply these data to the profile of the Gondwana series of India, it appears most probable that the coal-bearing sediments of the basin of Kusnezk correspond in general to the Lower Gondwanas (to the Talchirs and Karharbaris), and the Artinskian stage with the lower stage of the Damuda series (the Barākars), whilst the sediments on the Dwina, in which W. Amalizky has discovered a Glossopteris flora in association with a rich vertebrate fauna, may be considered as homotaxial with the upper stage of the Middle Gondwana beds (the sandstones and red clays of the Panchets). Such a comparison gives the conglomerates on the eastern slopes of the Ural Mountains described above a special interest; for if we ascribe to them a glacial origin, the period during which they were being laid down almost corresponds to that of the deposition of the Talchir boulder bed, the glacial origin of which admits of no doubt.

Returning to the consideration of the marine equivalents of the Carboniferous deposits of the Ural and the Timan Mountains, we must not forget the fact that, with the exception of the Ussuri country, no such deposits are known to occur throughout the wide expanse of Siberia. To the interesting limestones discovered by Dr. A. v. Bunge and Baron E. v. Toll in the outermost portion of the Lena-delta, no age less than Middle Carboniferous can be ascribed, to judge from the fauna buried in those limestones.[1]

South of the Ural Mountains, in the regions of the Ural and the Turgai and in the territory between the Ural and the Caspian Seas, no Upper Carboniferous deposits are known.

To judge from the palæontological collections which have been gathered by A. Romanowsky and J. Muschketow as well as a

[1] E. v. Toll, Géol Skizze der Neusibirischen Inseln. Mém. de l'Acad. Imp. des Sc., T. IX, No. 1 (1899), p. 8. This fact has evidently been overlooked by Frech when working out his map on the distribution of land and sea during the middle carboniferous epoch (the epoch of *Spirifer mosquensis*); for the outlines of the eastern arctic continent must be subjected to considerable corrections in view of the occurrence of middle carboniferous marine deposits along the lower course of the Lena (compare Fliegel, Die Verbreitung des marinen Obercarbon in Süd-und Ost-Asien. Ztschr. d. Deutschen Geol. Ges. Jahrg. 1898, S. 385—410, Frech, Lethæa geogn., II, Lfg. 2, Karte 3).

number of other investigators,[1] a complete series of deposits with *Spirifer mosquensis* and of overlying beds corresponding to the Upper Carboniferous strata of Eastern Russia are developed in Turkestan, as well as beds which are analogous to the Artinskian sediments of the Ural region, and among them beds with cephalopods which are perfectly identical with those of the Ural. As correctly noticed by A. Karpinsky,[2] the existence of similar deposits in Darwâs, which in a straight line is at a distance of 1,800 kilometers from the Ural, is very remarkable and brings out the importance of this province and of the surrounding mountainous districts, which are only at a distance of 650 kilometers from the Salt Range, for the study of the relations between the Upper Palæozoic strata of Russia and those of India. However scanty the data may be which E. Suess[3] has been able to gather from the materials collected by Stoliczka and K. Bogdanowitsch, partly on the Pamirs and the southern spurs of the Thian-Shan, partly in the western parts of the Küen-Lün Mountains, they point to the fact that the profile of the Upper Carboniferous strata of these mountainous regions belongs to the same type as the Uralo-Timanian deposits, and the data obtained by v. Loczy[4] and W. Obrutschew in Eastern Turkestan, in Nan-Shan and in China point on the whole in the same direction.[5]

Whilst there exist among geologists no differences of opinion of any importance with regard to the chronology of the Upper Palæozoic strata of Central Asia and China, we meet in the profiles of the Salt Range and the Himalaya with deposits the bathological position of which among the whole series of the Upper Palæozoic formations cannot be regarded as finally determined.

[1] The results of the study of these collections are found in G. Romanowsky, Materialien z. Geol. v. Turkestan, Lfg. 1—3, 1880—1890.

[2] A. Karpinsky, Ein Hinweis auf d. Vork. v. permo-carb. Schichten in Darwaz. Verh. d. Russ. K. Min. Ges. 2. Ser. Bd. XVIII, S. 219. Mat. z. Geol. Turk., Lfg. 2, S. 141.

[3] E. Suess, Beitr. z. Strat. Central Asiens. Denskchr. d. Math. Nat. Cl. d. Kais. Ak. d. Wiss. Wien. 1894.

[4] V. Loczy, Wiss. Ergebnisse d. Reise des Grafen Széchenyi in Ostasien. III. Bd., IV. Alth, 1898.

[5] Preliminary data obtained from the material gathered by him have been communicated to me by Obrutschew and have been incorporated in his published account of his travels. (Central Asien, Nord-China und Nan-Shan. Published by the K. Russ. Geogr. Ges.)

I consider it first of all necessary to take up the Salt Range in somewhat greater detail, because its stratigraphy has been investigated more fully than that of any other district in Asia with respect to the sequence of geological horizons as well as their palæontological contents. I consider it all the less superfluous to state my views on that profile, as the latter serves as a standard profile in discussions on the age not only of Asiatic, but also of Australian Palæozoic formations.

In the concluding volume of the work devoted to the description of the above-mentioned Indian deposits, Waagen,[1] on the basis of the investigations of Wynne and Warth as well as of his own observations, gives the following classification of the Palæozoic formations of the Salt Range, commencing from above :—

Topmost beds of the Upper Productus Limestone	= Chidru beds.
Cephalopoda beds „ „ „ „	= Jabi beds.
Lower and middle divisions „ „ „	= Khund Ghat beds.
Upper division of Middle Productus Limestone	= Kalabagh beds.
Middle „ „ „ „	= Virgal beds.
Lower „ „ „ „	= Katta beds.
Lower Productus Limestone or Upper Speckled Sandstone	= Amb beds.
Middle Speckled Sandstone.	
Lower „ „	= Boulder beds.

Of the subdivisions only the Middle Speckled Sandstone is unfossiliferous, and it is therefore not characterized palæontologically. The other horizons are all more or less rich in fossils. The latest discoveries in this respect have been made in the Lower Speckled Sandstone, from which two faunas have been obtained, one rich in *Conulariæ* and the other with peculiar *Conchiferæ* (*Eurydesma*). Both faunas are very similar to that buried in the lower productive deposits of New South Wales and the corresponding ones of Tasmania. Quite apart from the agreement in the palæontological contents of the Australian and Indian sediments, Waagen draws our attention to the interesting fact that in the very same series of Australian deposits glacial boulders similar to those of the Indian boulder beds, especially those of the Salt Range, have been found.

With respect to the age of the various subdvisions of the Productus limestone, Waagen's views underwent considerable changes between

[1] Waagen, Salt-Range Fossils, Vol. IV., Geol. Results, p. 241.

the years 1872 and 1895. At first[1] he was inclined to consider the whole series of Productus limestones to be of Carboniferous age. In the year 1879 he commenced the publication of his classical treatise on the fauna derived from the Productus limestone, and this afforded him an opportunity of giving expression to his essentially altered views on the age of the several members of the Productus limestone series, before the whole of the various monographs on the subject in question had yet appeared in print;[2] he ascribes a Carboniferous age only to the lower Productus limestones, whilst he refers the corresponding middle and upper limestones to the Permian system. Three years after the publication of the last part of the monograph on the fauna of the Productus limestone, Waagen fixed the age of the lowest subdivision to lie at the boundary between the Carboniferous and Permian periods, and in 1891, when he summarised the conclusions which he had drawn from the geological results of the study of the fauna in question, Waagen drew a parallel between the beds of Amb and Katta and the Artinskian deposits and the Limestone-Dolomite horizon of the Ural; further between the Virgal and in part also the Kalabagh beds and the Zechstein of Kostroma, whilst he sees in the whole of the remaining suite of the Productus limestone an equivalent of the rest of the Permian deposits of Russia.

One need not be astonished at the change in the views of a scientist of the first rank; for up to the present it is only in two countries (Russia and North America) that the whole series of the Upper Palæozoic formations is known from typically marine deposits; and as long as the fauna of these sediments, especially those of Russia, had not received a sufficiently exhaustive treatment, there did not exist any palæontological standards of comparison for the determination of the relative age of strata, standards which could have been applied to such a complex of horizons as presented by the Productus limestone, the Upper Palæozoic strata of the Himalaya, the corresponding formations of Australia, etc. Consequently opinions on

[1] Waagen, Mem. Geol. Surv. of India, Vol. IX, Pt. 2 (1872), p. 353. It will not be amiss here to point out that it was Russia where the first correction of this view on the age of the Productus limestone originated, and that it was A. Karpinsky who, without being in possession of palæontological data with respect to the various sub-divisions of that series of limestones, gave a very definite expression of the view that among the strata of the Salt Range here referred to there are equivalents of the Russian Artinskian sediments.

[2] Waagen, Z. d. D. G. G. 1884, S. 881.

the subject could not be based on a comparison with strata, the age of which was undoubted, so that the only available guiding principles were general considerations of a biological character. I have, however, pointed out before how reliable the foundations are which are furnished by such characters, and I intend to refer to them again in the sequel.

At the time when the first part of my treatise was already in the hands of the printer, there appeared a comprehensive contribution to the geology of the Salt Range from the pen of Noetling.[1] This scientist denied the existence of Carboniferous depcsits in the Salt Range, and considered the boulder beds as well as the overlying *Eurydesma* and *Conularia* sandstones and the Warcha-beds as homotoxial with the Rothliegende, whilst all the subdivisions of the Productus limestone, according to his opinion, belong to the Thuringian stage of the Zechstein Noetling, in his treatise, lays repeated stress on the impossibility of drawing a dividing line based on lithological character between the upper beds of the Thuringian stage and the lowermost horizons of the Trias, and points out that in the Salt Range the replacement of the Neodyas or Upper Permian sea by the sea of the Trias has been perfectly gradual. Without entering here on an analysis of the chronological correlation adopted by Noetling, a task which I will defer, I consider it appropriate to remark that he adduces scarcely any fresh palæontological facts which would form a complement to Waagen's work, and that his deductions rest essentially on the forms described by the last-named author. This is why I do not see any sufficient reasons to abandon the scheme proposed by Waagen in his monographs, when comparing the Brachiopod fauna described by myself with that of the Productus limestone of the Salt Range; and as a matter of fact I consider it of little importance whether we carry out our synchronisation according to Waagen's scheme or according to the zones proposed by Noetling.

From the tables in which our knowledge of the distribution of the Brachiopods from the Timan and Ural Mountains according to horizons and sub-horizons is summarized, it is seen that the following Timano-Uralian forms are represented in the Salt Range:—*Dielasma elongatum*, Schloth.; *D. truncatum*, Waag.; *D. itaitubense*, Derby.; *Hemiptychina sublaevis*, Waag.; *Nothotyris*

[1] Noetling, Neues Jahrb. f. M., Beil. Bd., XIV, 1901.

nucleolus, Kut.; ***N. simplex***, Waag.; ***N. Wurthi***, Waag.; ***Camarophoria superstes***, Vern.; ***C. globulina***, Phill.; ***Athyris pectinifera***, Sow.; ***A. Royssiana***, Keys. = ***A. acutimarginalis***, Waag.; ***Hustedia remota***, Eichw. = ***H. grandicosta***, Waag.; ***H. indica***, Waag.; ***Spiriferina ornata***, Waag.; ***Sp. cristata***, Schloth.; ***Sp. Panderi***, Moell. = ***Sp. nasuta***, Waag.; ***Spirifer striatus***, Mart.; ***Sp. fasciger***, Keys.; ***Sp. Marcoui***, Waag.; ***Martinia semiplana***, Waag.; ***Reticularia elegantula***, Waag.; ***Streptorhynchus pelargonatus***, Schloth.; ***Derbyia regularis***, Waag.; ***D. grandis***, Waag.; ***Rhipidomella Pecosi***, Marcou; ***Chonetes morahensis***, Waag.; ***Ch. trapezoidalis***, Waag.; ***Aulosteges dalhousii***, Dav.; ***Productus Humboldti***, d'Orb.; ***Pr. Cora***, d'Orb.; ***Pr. lineatus***, Waag.; ***Marginifera typica***, Waag.; var. ***septentrionalis***, mihi.

This list can be extended, if we add the forms which replace closely related forms from the Ural:—

Salt Range.	Ural and Timan.
Dielasma breviplicatum, Waag.	***Dielasma dubium***, mihi.
„ ***problematicum***, Waag.	„ ***timanicum***, mihi.
Terebratuloidea Davidsoni, Waag.	*Terebratuloidea triplicata*, Kut.
Camarophoria Purdoni, Dav.	***Camarophoria mutabilis***, mihi.
„ ***humbletonensis***, Howse.	„ ***applanata***, mihi.
Spirifer alatus, Schloth.	*Spirifer Dieneri*, mihi.
Martinia elongata, Waag.	***Martinia applanata***, mihi.
Streptorhynchus pectiniformis, Dav.	***Streptorhynchus Halli***, Derby.
Schizophoria janiceps, Waag.	***Schizophoria juresanensis***, mihi.
Chonetes strophomenoides, Waag.	***Chonetes Moelleri***, mihi.
Productus spiralis, Waag.	***Productus uralicus***, mihi.
„ ***aratus***, Waag.	„ ***transversalis***, mihi.
„ ***Purdoni***, Dav.	„ ***irginæ***, Stuck.

If we add these forms to the list of the forms which are common to the Ural and Timan mountains and to the Salt Range, the total reaches 44, of which 16 have been found in the lower, 33 in the middle and 19 in the upper Productus limestone.

If we institute a still more detailed comparison, we discover that of the 16 forms which are common to the lower Productus limestone (the Amb beds) and the Uralo-Timanian Carboniferous strata, 5 forms belong to the *Omphalotrochus* horizon, and among them *Spirifer Marcoui*, Waag., which up to the present seems to be confined to this horizon; another 8 forms are from the Cora horizon; and among them *Productus Cora*, d'Orb., which is only rarely met with in the middle Productus limestone, predominates as well in Eastern Russia as

in the Salt Range; finally 15 forms found in the lower Productus limestone have also been discovered in the Schwagerina horizon of the Ural mountains; but almost all of them (13) belong to the species which are either rare in this horizon within the Salt Range, or which pass into the overlying middle Productus limestone.

Continuing our investigation into the middle Productus limestone, we soon notice that in the lower section, the Katta beds the latter have 15 forms in common with the corresponding sediments of Russia, in which 3 forms have been found in the Omphalotrochus horizon, 3 in the Cora horizon, and 12 in the Schwagerina horizon, and among the latter particularly so common a form as *Notothyris nucleolus*, Kut., as well as *Hustedia indica*, Waag., *Streptorhynchus pelargonatus*, Schloth., *Derbyia grandis*, Waag., and *Streptorhynchus Halli*, Derby, which are no less common in the Schwagerina horizon of the Ural and the Timan. Still more striking is the resemblance between the middle section of the middle Productus limestone (the Virgal beds) and the Schwagerina limestones of the Ural and the Timan mountains: among the 22 species which are common to the corresponding horizons of the Salt Range and the Ural and Timan there is not one which cannot be found in the Schwagerina horizon, notwithstanding their comprising such characteristic forms as *Camarophoria superstes*, Vern., *Hustedia remota*, Eichw., *Spiriferina Panderi*, Moell., *Spirifer fasciger*, Keys. (very rare in the lower strata of the Salt Range), *Martinia semiplana*, Waag., *Derbyia regularis*, Waag., *Derbyia grandis*, Waag., *Chonetes morahensis*, Waag., *Terebratuloidea triplicata*, Kut., *Camarophoria mutabilis*, Mihi, *Streptorhynchus Halli*, Derby, and *Marginifera typica*, Waagen. Not without significance is the fact that both in the Schwagerina horizon of the Ural and in the Virgal beds representatives of the family of the *Lyttoniidæ* make their appearance, which mark a very characteristic and definite moment in the history of the Upper Palæozoic strata of Russia.

In the upper section of the middle Productus limestone, the Kālabāgh beds, the palæontological agreement with the Schwagerina horizon is considerably less noticeable, there being no more than 11 common forms. Slightly greater is the number of species common to the Schwagerina horizon and the lower section of the upper Productus limestone (the Khund Ghat beds), and nearly the same thing holds good with respect to the Cephalopod beds of the Upper

Productus limestone (Jabi beds), which enclose 13 forms occurring also in the Schwagerina limestones of the Ural and the Timan.

Hence a comparison of the brachiopod fauna of the Upper Carboniferous sediments of the Ural and the Timan Mountains with that of the various subdivisions of the Productus limestone of the Salt Range makes it pretty clear *that the lower Productus limestones—the Amb beds—are most correctly co-ordinated with the Spirifer Marcoui and Omphalotrochus Whitneyi horizon of the Ural and the Timan, and that we may see in the Russian Schwagerina horizon the most natural equivalent of the larger part of the middle Productus limestone, whilst the Cora horizon is to be considered as homotaxial with the upper Amb beds and probably also with the lower horizons of the middle Productus limestones or the Virgal group (of Noetling).*

In this correlation the Kālabāgh beds and the upper Productus limestone find (at least as a whole) their counterpart in the Artinskian sediments of the Ural mountains and their equivalents on the Timan.

This result is in considerable disagreement with the predominant views on the age of the various subdivisions of the Productus limestone of the Salt Range, and virtually leads us back to the original conception that they are of Carboniferous age. I quite foresee that against my deductions the objection will be raised that they are based solely on a comparison of the brachiopods; but I can support them by the results of an investigation into other classes of the animal kingdom. I have something particular to say on the Cephalopods, especially the Ammonites.

The monograph of A. Karpinsky on the ammonites of the Artinskian sediments has established the important facts that the representatives of this fauna cannot be considered as immigrants into the Ural area, but that they must be regarded as autochthonous and that the Sicilian ammonite fauna described by Gemmellaro, apart from some Arcestidæ, possesses an Artinskian facies. A Sicilian form, *Medlicottia Trautscholdi*, is, according to Karpinsky, identical with the Uralian *M. Orbignyana*; two others, *Gastrioceras sosiense* and *Agathiceras Suessi*, are closely related to *G. Suessi* and *Ag. uralicum* respectively from the Artinskian sediments, in addition to which 8 species described by Gemellaro remind one forcibly of Uralian ones. "The most essential deviation of the Sicilian fauna," says

Karpinsky, "appears to lie in the appearance of the complex Arcestidæ (*Cyclolobus* or *Waagenoceras* and *Hyattoceras*), which are unknown in the Uralian area. Furthermore, many genera which are common to Sicily and the Ural mountains are represented in the former country by more complex forms. All this points to the Sicilian fauna being of a somewhat later origin than that of the Ural, notwithstanding its being closely related to the Artinskian fauna. On the other hand it is possible that the difference referred to is due to local causes.

The more complex Arcestidæ may for instance belong to a more southern area. That the latter explanation, in itself quite natural, is possibly correct, has not been recognised by the majority of the scientists who have dealt with the Artinskian sediments, and in conformity with Waagen's mode of procedure it became customary to assign to the Sicilian Fusulina limestones a position considerably higher than Artinskian. Co-ordinating the latter with the Katta and Amb beds, Waagen considers the Fusulina limestone of Sicily as homotaxial with Virgal and Kālabāgh beds, and he places the Cephalopod beds of the Salt Range or the Jabi beds still higher, in line with the Upper Permian deposits of Russia. In my opinion such a co-ordination was hardly intended by A. Karpinsky, when he spoke of the possibility of the *somewhat* later origin of the Sicilian fauna with respect to the Artinskian sediments. With respect to the cephalopod beds of the Salt Range, A. Karpinsky, in conformity with the data obtained by me from a study of the Artinskian brachiopods, considers them as later than Artinskian, and in placing the latter in line with the middle Productus limestone, he assigns to the former a stratigraphical position below the upper Productus limestone of the Panjāb.

These conclusions followed quite naturally from the palæontological data then available. At present, however, when the Upper Carboniferous brachiopod fauna of the Ural and the Timan has been worked out, and when the deductions based thereon point with sufficient clearness to the homotaxial equivalence of the Upper Carboniferous division in Northern and Eastern Russia with the Amb, Katta, and Virgal beds in the Salt Range, a correction of the older conceptions becomes unavoidable. I have especially to observe that since the publication of the treatise of A. Karpinsky and of my own work, there has been gathered from the Artinskian deposits of the Ural an extensive supplementary material, and among it cephalopods, which

promise, as soon as worked out in detail, to contribute essentially towards the solution of the problem concerning the correlation of the Upper Palæozoic strata of Russia with those of India.[1]

Quite recently some facts have been discovered with respect to the Salt Range which are not without interest in connection with the subject at present under discussion; for it is now settled that the cephalopods are not restricted to the Jabi and Chideru beds, but are also met with in strata corresponding to the Kālabāgh beds, and according to Noetling numerous specimens of *Xenodiscus carbonarius*, Waag., have been found in the former. Similarly Diener has worked out the limestone fauna of Chitichun in the Himalaya, and he co-ordinates it with the upper section of the middle Productus limestone of the Salt Range (the Virgal and Kālabāgh beds) as well as with the Artinsk horizon of Eastern Russia. Among the members of this fauna Diener describes a *Popanoceras* (*Stacheoceras*) *Trimurti*, Diener, which possesses its nearest analogue in the Sicilian Fusulina limestones of corresponding age. F. Noetling maintains on the basis of the most recent collections of Walker, that two faunas are found in the section of Chitichun; an older one with *Productus semireticulatus* and a younger one, which either characterises the complete suite of the Productus limestones or at least its middle and upper subdivisions (the Virgal and Chideru beds in Noetling's sense). In connection with the subject dealt with by us the possibility of such a division is not a matter of great moment; for it involves only the recognition of the fact that the profile of Chitichun contains, besides Artinskian strata, also equivalents of the Schwagerina horizon of Russia. We are confirmed in this view by a comparison of the brachiopod fauna from the already mentioned Russian deposits with the fauna worked out by Diener, which demonstrates the occurrence in the Chitichun profile of forms which hitherto had been exclusively or mainly confined to the Schwagerina limestones of Russia (*Productus simensis*, mihi = *Pr. Cora*, Diener, *Productus transversalis*, mihi = *Pr. semireticulatus*, Diener, *Marginifera typica*, Waag., *Spirifer tibetanus*, Dien., *Camarophoria mutabilis*, mihi = *C.* aff. *crumena*, Dien., *Notothyris nuclecolus*, Kut.

[1] I draw, for instance, attention to the fact that I have found in the palæontologically well characterized Artinskian sediments of the Northern Geese Cape on Nowaya Semlya remains of a *Medlicottia* which reminds one strongly of *Medlicottia Wynnei*, Waagen, possessing a similarly complicated suture-line.

which reminds one vividly of *N. subvesicularis*, Dav.) as well as of species which are exceedingly common in the Artinskian deposits (*Productus cancriniformis*, mihi, *Productus mongolicus*, Diener, *Spirifer fasciger*, Keys., *Sp. Wynnei*, Waag., *Martinia semiplana*, Waag.). Whilst therefore I consider it highly probable that part of the profile of Chitichun has to be placed side by side with the uppermost horizons of the Carboniferous system, I have to declare myself in agreement with Diener when considering the beds with *Popanoceras Trimurti* as homotaxial with the Russian Artinskian stage; and we receive consequently a further testimony in favour of the correlation of the Virgal beds or the middle section of the middle Productus limestone with the Schwagerina horizon of Russia, and of the Kālabāgh beds together with part of the upper Productus limestone with the Russian Artinskian sediments.

Very important is also the discovery of remains of *Helicoprion*, Karpinsky, in the upper Productus limestone of Chideru. Although Koken suspects that we have here to deal with a species different from *H. Bessonovi*, Karp., from the Artinskian deposits of the Ural Mountains, there can be no doubt that the period of existence of such a specialized animal type must have been restricted. In the Ural Mountains all localities of *Helicoprion* lie within the Artinskian horizon. But the horizontal distribution of that genus is rather wide; for at the present moment we have representatives of the genus, which possibly are identical with *H. Bessonovi* and in any case are closely related to it, from North America, Japan, India, and Australia.

In favour of the indicated correlation, and in any case in contradiction of the view that the whole series of the Productus limestone is to be assigned to the Permian system are the results of a comparison of the pelecypod fauna. Although this class of mollusca remains to be described as far as the Upper Carboniferous deposits of Russia are concerned, the available data justify me in referring to some interesting facts concerning them. Within the Upper Carboniferous deposits of the Ural and the Timan Mountains pelecypoda are most plentiful in the Cora and Schwagerina horizons. In the Salt Range the lower Productus limestone is relatively poor in representatives of this class.[1] Somewhat richer is the middle division, from which Waagen has described 10 species—7 from the

[1] According to Waagen only 4 species have been found in the lower Productus limestone.

Virgal and 5 from the Kálabágh beds.[1] The largest number of pelecypods has been reported from the upper Productus limestone; 18 species occur in the beds of Khund Ghat, 10 in the cephalopod beds of Jabi, whilst finally the beds of Chideru enclose the richest and most varied fauna, consisting of 31 species.

In the Omphalotrochus and Cora horizons we meet only three forms which show a great likeness to Indian forms: *Aviculopecten elegantulus*, Stuck., which in many respects reminds one of *A. derajatensis*, Waag., from the Virgal beds, *Pseudomonotis pseudoradialis*, mihi, closely related to *Ps. radialis*, Phill., and still more closely to *Ps. radialis*, Waag., and *Lima retifera*, Shum., which according to Waagen is very similar to *L. Footei*, Waag., also obtained from the Chideru beds. An incomparably larger number of forms, which agree with Indian ones, are met with among the pelecypods of the Schwagerina horizon, where, apart from *Aviculopecten elegantulus*, Stuck., which reminds one of *A. derajatensis*, Waag., *Macrodon semilarvis*, Keys., is very common, which is distinguished from *M. geminum*, Waag., from the Virgal and Kálabágh beds solely by its somewhat finer ribs. Besides these, there have been found in the same horizon in the Ural mountains *Myophoria praecox*, Waag. (Chideru beds), *Pecten prototextorius*, Waag. (Khund Ghat and Jabi beds) and *Lithodomus simplicissimus*, mihi, which is possibly identical with, and in any case closely related to, *L. atavus*, Waag. If we add that in the Schwagerina limestones there has been discovered a very conspicuous *Pseudomonotis*, which is not distinguishable from *Ps. gigantea*,[2] Waag., we cannot deny the resemblance of the Upper Carboniferous pelecypod fauna of the Ural mountains to that obtained from the middle and upper Productus limestone of the Salt Range. In no case are the data derived from a study of the pelecypod fauna contradictory to the deductions concerning the homotaxiality of the Schwagerina limestones of Russia with the Virgal beds and partly also with the Katta beds of the Salt Range, and in any case they must be considered as supplying a stronger proof than is furnished by the discovery, in the Virgal beds of *Pseudomonotis garforthensis*, King, the only lamellibranch which according to Waagen's opinion proves the Permian age of these deposits.

[1] In the Katta beds not a single specimen of a pelecypod has been discovered.

[2] The position of this species in the Productus limestones is not known with certainty, but Waagen believes it to have been obtained below the middle Productus limestones.

To confirm his views on the age of the Virgal beds, Waagen draws attention to a group of five forms which stamp the fauna of those beds as comparatively young; but, as we have seen above, it is not otherwise with the fauna of the Schwagerina horizon of Russia. Doubtless we shall be able to pass from the sphere of more or less probable conjecture to the region of well-ascertained facts only when the pelecypod fauna of the Artinskian deposits are as completely known as is the case with the brachiopods. Nevertheless, the rich material gathered within the past years entitles us to maintain that the resemblance of the pelecypod fauna, already well marked in the case of the Schwagerina horizon on one hand and the Productus limestones on the other, must be still more striking in the case of the Artinskian deposits. On the contrary, in the typical Permian sediments of Russia, very complete information on the fauna of which we owe to the monograph of A. Netschajew, we find in a purely marine facies close upon 100 different representatives of the genera and subgenera *Ostrea*, *Prospondylus*, *Lima*, *Pecten*, *Aviculopecten*, *Pseudomonotis*, *Liebea*, *Bakewellia*, *Modiola*, (*Lithodomus*), *Modiolopsis*, *Modiolodon*, *Macrodon*, *Nucula*, *Leda*, *Dolabra* (?), *Schizodus*, *Solemya*, *Pleurophorus*, *Astarte*, *Cardiomorpha*, *Edmondia*, *Solenopsis*, *Crassiconcha* and *Alorisma*, and among all these only one is in common with the middle and two with the upper Productus limestone. To ascribe such a great difference solely to the peculiarities of the Permian sea of Russia is hardly justifiable, the less so as a great number of the enumerated genera and subgenera from the Permian deposits of Russia are also found in the Productus limestone of India.

The corallian and bryozoan fauna too of the Productus limestone and of the Uralo-Timanian Upper Carboniferous deposits are capable of furnishing some materials for proofs. Both are restricted to the middle and upper divisions of the Productus limestones.[1]

The total of the Bryozoa described by Waagen and Pichi does not exceed 18, of which only four are met with in the middle division of the Productus limestone. A comparison of the forms worked out by the above-mentioned palæontologists with those from the Upper Carboniferous of Russia and studied by A. Stuckenberg teaches the following facts: *Fenestella perelegans*, Meek, from the middle Productus limestone, is very close to *F. elegantissima*, Eichw., from the

[1] In the lower Productus limestone occur two corals (*Orbipora ambiensis* and *Stenopora hemisphærica*) and two Bryozoa (*Polypora vermicularis* and *Thamniscus serialis*).

Schwagerina horizon; *F. jabiensis*, W. et P. (middle and upper Prod. limestone), is hardly distinguishable from *F. foraminosa* (Schwag. hor.); *Polypora megastoma*, de Kon. (middle Prod. limestone), has been found in the Upper Carboniferous limestone of the Ural; *P. ornata*, W. et P. (middle and upper Prod. limestone), is compared by the authors with *P. orbicribrata*, Keys., *P. subquadrata*, Toula, and *P. cyclopora*, Eichw., forms which have been obtained from the Schwagerina horizon; *P. sykesi*, deKon. (middle Prod. limestone), approaches *P. papillata*, M'Coy (Schwag. hor.); *P. biarmica*, Keys. (upper Prod. limestone), is identical with the species bearing the same name from the Schwagerina horizon; *Phyllopora cribellum*, W. et P., is near *Ph. micropora*, Stuck. (Cora hor.); *Synocladia virgulacea*, Phill. (middle and upper Prod. limestone), is very closely related to *S. arboracea*, Stuck. (Schwagerina hor.); similarly, *Goniocladia Indica*, W. et P. (middle Prod. limestone), and *G. concatenata*, Eichw. (Schwag. hor.); *Thamniscus serialis*, W. et P. (lower and middle Prod. limestone), reminds one vividly of *T. timanicus*, Stuck. (Schwag. hor.); and finally *Acanthocladia anceps*, Schloth. (middle Prod. limestone) bears more resemblance to *A. carbonica* (Schwag. hor.) than to the Permian representatives of Schlotheim's species. Consequently, of the total number of the Bryozoa of the Productus limestone, eleven forms are either identical with representatives of the Timano-Uralian fauna or at least remind one forcibly of them. Of these one belongs to the middle Productus limestone and ten to the Schwagerina horizon of the Ural and Timan mountains. The resemblance with the upper Productus limestone extends only to five forms of the Schwagerina horizon, and with the lower Productus limestone only to one. From this it appears clearly that an examination of the Bryozoan fauna leads to the same result, namely, the agreement of the fauna of the Schwagerina limestone of Russia with that of the middle Productus limestone.

A lesser number of points of contact are furnished by the Corallian fauna, which is scantily represented in the Productus limestones and which receives a peculiar character from the predominance of types which resemble Lower Palæozoic ones. Notwithstanding this, a considerable resemblance with the Russian Upper Carboniferous fauna is unmistakable.

Michelinia Abichi, W. et W. (upper Prod. limestone), is very near *M. tenuisepta*, Phill. (Schwag. hor.); *M. placenta*, W. et W. (upper Prod. limestone), resembles, according to Waagen and Wenzel, *M. favosa* (Schwag. hor.) rather strongly; *Geinitzella columnaris*, Schloth.

(middle and upper Prod. limestone), is common in the Cora and Schwagerina horizons; *G. crassa*, Lonsd. (middle? and upper Prod. limestone), has also been found in the Schwagerina horizon; *Amplexus Abichi*, W. et W. (upper Prod. limestone), is scarcely distinguishable from *A. coralloides* (Schwag. hor.); *Dybowskiella grandis*, W. et W., is very near *D. labiata* (Cora. and Schwag. hor.).

According to my own opinion all that has been said is directly in contradiction to the conclusions of Waagen and his followers, who see in the series of Productus limestones the counterpart of the Permian deposits of Russia; and the Productus limestones have to occupy, in the general chronological scheme, a position lower than that assigned to them by Waagen, Noetling, and other geologists.

There is only one fact of a geological character which does not harmonise with this lower position and that is the gradual petrographical transition, insisted upon by Noetling, from the uppermost horizon of the upper Productus limestone to the lower Triassic beds (the Scythian stage). According to Noetling's statement, which is based on the sections of Chideru and Virgal, the repetition of the same rocks within a succession of rocks which belong to the upper Productus limestone and to the Lower Trias furnishes a powerful argument in favour of the close relation between the Triassic and Permian sediments of the Salt Range, and the whole question with respect to the discordant or transgressive stratification appears to him pointless under the circumstances. The thorough palæontological disagreement between the strata of Chideru and those of the Scythian stage, which are separated from the former by only a few yards, is explained by Noetling on the supposition that the end of the Permian period and the beginning of Triassic times were characterised in the Salt Range by a frequent change in the lithological facies, which could not but influence the organic life very markedly. In this change Noetling finds the best explanation of the sudden extinction of the brachiopods. But this explanation is hardly applicable to the fact pointed out by Waagen that, as far as his information went, *not a single form can be traced from the Chideru beds into the Triassic Ceratite sediments.* A sharply defined boundary of this kind is rather a proof of the transgressive deposition of the Triassic upon the palæozoic strata of the Salt Range. Geologists who have worked in European Russia are acquainted with quite a number of instances where, notwithstanding the absence of a recognisable lithological boundary, a transgressive superposition of this

or that sediment on sediments of older date has been proved by palæontological data. I cite here only the classical profile on the river Popowka near Pawlowsk where the discovery of Trochilisca in the upper portions of homogeneous argillaceous limestones has sufficed to prove the existence of Devonian sediments upon Lower Silurian strata without a well-marked division line between them. Those geologists also who have occupied themselves with the Mesozoic deposits of Russia will remember quite a number of instances where, within a succession of sediments of which it was supposed that they had been deposited uninterruptedly in the same sea-basin, the existence of considerable breaks was established later on, breaks which pointed to a transgressive deposition of younger strata upon others which, though lithologically similar, were chronologically far removed. Confining myself to these remarks, it appears to me that the facts adduced by Noetling do not possess the force of convincing proofs of a gradual replacement of a Permian sea of the Salt Range by the Triassic, and that the palæontologically sharply marked boundary between the corresponding sediments speaks for a transgressive deposition of the Scythian stage on the Productus limestone.

What the relation is between the zone of *Otoceras Woodwardi* and *Ophiceras tibeticum* in the Himalaya to the profile of the Salt Range is a problem which cannot yet be solved definitely. Its parallelism with the upper horizon of the Productus limestone is based first and foremost on the identity of *Medlicottia Wynnei*, Waag., from the Salt Range with *M. Dalailamae*, Diener, which according to Krafft (Ueb. d. perm. Alter der Otoceras Stufe des Himalaya. Centralbl. f. Min., Geol. u. Pal. 1901, No. 9, S. 275-279) are one and the same species. As, however, Waagen's original specimen, according to Krafft, is badly preserved, the establishment of the identity of the two species requires confirmation on the basis of more satisfactory material. It is all the more necessary to be cautious as certain *Medlicottiæ* reminding one strongly of *Medlicottia Wynnei*, Waag., have been already found in the Artinskian strata of Russia. In any case, before the correlation proposed by Noetling (N. J. Beil. Bd. XIV, Taf. zu S. 468) can be definitely accepted, it is imperative that an unbroken palæontological connection of the zone of *Cyclolobus Oldhami* and *Xenaspis carbonarius* with the deposits containing *Otoceras Woodwardi* be established.

Summarising the discussions concerning the relations between the Upper Palæozoic formations of Russia and India, we arrive at the

conclusion that the Russian Upper Carboniferous sediments belonging to the Omphalotrochus and Schwagerina horizons have to be considered as homotaxial with the Productus limestones from the Amb beds upwards to the Virgal beds inclusively. The overlying parts of the Productus limestone correspond in all probability with the Permo-Carboniferous of Russia (the Artinskian horizon *CPg* and the limestone dolomite horizon *CPc*) and possibly with the lowest horizons of the Permian. A final decision on the matter must be postponed until the Russian Permo-carboniferous fauna has been completely worked out. As far as our present knowledge allows us to judge, the existence of sediments in the Salt Range which are likely to be homotaxial with the upper horizons of the Permian of Russia is highly problematical.

In this correlation the Warchá and Dandot group (with *Conularia laevigata* and *Eurydesma globosusm*) find their place in the Middle Carboniferous division of the Ural, on the eastern slope of which the conglomerates (possibly of glacial origin) appear to be the equivalents of the Talchir boulder beds of India.

In the present state of our knowledge the following scheme of correlation of the Upper Palæozoics of the Salt Range and of the Ural and Timan mountains appears to be the most probably correct one:—

Salt Range.		Ural and Timan Mountains.
Upper Productus Limestone (thickness about 100 meters).	Chideru beds. Jabi beds. Khund Ghat beds.	Lower Permian formations of European Russia. Limestone-Dolomite horizon *C Pc* and Artinskian deposits *C Pg*.
Middle Productus Limestone (thickness about 100 meters).	Kālabāgh beds. Virgal beds. Katta beds.	Schwagerina horizon (thickness 50—60 meters). Cora horizon (thickness 70 – 100 meters).
Lower Productus Limestone (thickness about 66 meters).	Amb beds.	Omphalotrochus horizon (thickness 60—70 meters).
Panjāb Stage of Noetling (thickness about 200 meters).	Warcha beds (Speckled sandstone and Lavender Clay). Dandot beds. Talchir (boulder) beds.	Conglomerates and Breccias on the eastern slopes of the Ural Mountains. / Middle Carboniferous Division. Sediments with *Spirifer mosquensis* on the eastern slopes of the Ural Mountains.

After these discussions on the stratigraphical position of the Productus limestones of the Salt Range, it remains to say something with respect to the Palæozoic deposits of Djulfa, Timor, Sumatra, Lo-ping in the province Kiang-si, of the Ussuri region, and with respect to the newly discovered strata with *Lyttonia* in Japan.

The remarkable fauna of the marly limestones of Djulfa, which became first known by the investigations of Abich, has been studied lately by Arthaber after a visit, undertaken in the company of Fr. Frech, to the valley of the Araxes, where the two scientists gathered an extensive collection, which quite essentially supplemented that made by Abich. This fauna excites special interest from the fact that in it there have been found, besides types which are peculiar to the Upper Carboniferous as well as to the Artinskian strata of Russia, two types of Ammonites: species of *Gastrioceras* which remind one strongly of some Upper Carboniferous and Artinskian forms (*Gastrioceras Abichi* which is near *G. Suessi*), and Ceratites-like Ammonites (*Otoceras, Hungarites*). Such apparent mixture of two faunas of different types gave rise to the conjecture that in the extensive suite of marly limestones we had in reality to deal with two palæontologically different horizons. After a personal inspection of the profiles of the Araxes valley Arthaber does not deny the possibility of such a state of things, but he observes correctly that it is impossible to form a final opinion on the matter without at first studying the extensive series of marly limestones bed by bed. A hurried visit like the one paid by Arthaber and Frech to the Araxes valley rendered such a mode of procedure quite impossible. For this reason Arthaber considers it possible that the whole of the Djulfa fauna is contemporaneous. If we grant the correctness of this view, we may consider Arthaber's deduction as sufficiently proved, according to which the marly limestones of Djulfa are of the same age as the Khund Ghat and the Jabi beds; but we must not forget at the same time the stratigraphical relationship of the sediments of Djulfa and of the Artinskian deposits of Russia.[1] However this may be, the question concerning the two faunas of the Araxes profile must at present remain open; and in the same way we cannot expect a satisfactory solution of the problem of the relationship

[1] The occurrence of the genera *Otoceras* and *Hungarites* in the fauna of Djulfa is not of paramount importance for the assumption of a younger age, for Ceratite-like forms are also found in the Upper Carborniferous deposits, as has been pointed out already.

of the marly limestones of Djulfa to the Upper Carboniferous formations, before the necessary material has been collected for a systematic exploration of Transcaucasia.

Whilst we may have reasonable doubts on the stratigraphical position of the fauna of Djulfa, we can assert with the greatest confidence that the fauna of Timor, which has been worked out by Beyrich and Rothpletz, is of the same age as the Artinskian deposit of the Ural. We are justified in this conclusion by the great resemblance of the two faunas, which has not escaped Rothpletz, as well as by their striking agreement (especially with regard to the brachiopods) with the Schwagerina beds of East Russia, which points to a close stratigraphical relationship of the shales and limestones of Timor with the Upper Carboniferous deposits of Russia.

As far as Sumatra is concerned, the existence of equivalents of the Upper Carboniferous strata of Russia could be surmised from the treatise of Roemer, and a paper by Fliegel furnishes further materials for comparison; but unfortunately the latter author has had to deal with material which was not collected by himself, and in consequence of this he is not in a position to assign the various forms to definite horizons. In any case I am of opinion that Fliegel was amply justified in the conclusion that in Sumatra deposits exist which correspond to the Moscovian stage as well as, to a certain extent, to the Upper Carboniferous of Russia.

From the island of Borneo there are known Upper Carboniferous sediments which may correspond to the Schwagerina deposits of the Ural. The same position is probably occupied by the limestones of Tenasserim which contain plenty of *Moellerinæ* accompanied by a Productus of the type of *Pr. sumatrensis*, Roem. Passing over a number of localities in Tonkin and Southern China, where partly Middle, partly Upper Carboniferous deposits exist, we meet with the richest Upper Carboniferous fauna in the province of Kiangsi near Lo-ping, a fauna, which was discovered by Richthofen and worked out by Kayser. This fauna, whose age appears to me to be most probably the same as that of the Schwagerina strata of Russia, awakens our interest by the discovery in it of *Richthofenia* and *Lyttonia* and serves as a connecting link between the Salt Range and the Ussuri region, where, as we shall see presently, the resemblance with the fauna of the Productus limestone is particularly striking.

With respect to the limestones cropping out in the vicinity of

Vladivostok, the sum total of our knowledge was contained in a communication which I had made on a small collection gathered by Margaritow at the Tawaisa bay, north-east of Vladivostok in the innermost angle of the Ussuri bay. By the expedition of D. Iwanow, which started the exploration of the Ussuri region in 1888, interesting supplementary material has been got together from the limestones of the Tawaisa bay as well as from other localities of that area, and it will be shortly described by me in a separate work. For the present, the following statements will suffice.

A rich palæontological haul was made in the Tawaisa bay, where, according to a communication of D. Iwanow, light-grey, coarsely crystalline limestones crop out, the most instructive section occurring near the southern cape of the bay. The upper portions of the limestone are of a uniform grain, and very strong clayey partings are rare. But the more one approaches the deeper horizons, the more frequent become intercalated flints and clays, which alternate with thin layers of limestone. The lowest horizons consist of calcareous sandstones and siliceous-argillaceous slates of a green colour, which rest on brecciated or conglomeratic rocks. The series of the upper limestone comprises not more than 25 meters in a total of 50 meters. In the collection of Iwanow the fossils are not accompanied by any statement of the strata in which they were found, but the adhering fragments of rock render it possible to state that the clayey layers are specially rich in crinoid stalks, bryozoa and corals, as well as in impressions and cores of *Productus Cora*, d'Orb. On the whole the same forms repeat themselves, it appears, throughout the whole series. Of the brachiopods which occur here the following may be mentioned:— *Hemiptychina inflata*, Waag., *Notothyris nucleolus*, Kut., *Camarophoria Margaritovi*, mihi, *C. Purdoni*, Waag., *Rhynchophora Nikitini*, mihi, *Hustedia remota*, Eichw., *H. indica*, Waag., *Spiriferina cristata*, Schloth., *Spiriferella Keilhavii*, Buch., *Spirifer fasciger*, Keys., *Sp.* aff. *alatus*, Schloth., a *Martinia* of the type of *M. semiglobosa*, mihi, *Reticularia lineata*, Mart., an *Enteletes* near *E. hemiplicatus*, *Productus Purdoni*, Waag., *Pr. irginæ*, Stuck., *Pr. asperulus*, Waag., *Pr. Wallacei*, Derby, *P. Weyprechti*, Toula, *Marginifera typica*, Waag., *M. ovalis*, Waag.

The same limestone overlying a conglomerate has been met with by D. Iwanow between the mouths of the rivers Mai-chä and Zymuchä in the inner angle of the Ussuri bay, and here *Camarophoria*

Margaritovi, mihi, *Camarophoria*, sp., *Reticularia rostrata*, Kut., *Productus irginæ*, Stuck., and *Pr. Cora*, d'Orb., have been found. In this limestone a great quantity of *Fusulinæ* are met with, which are distinguished by their large dimensions and the great number of whorls (17-18, even 20).

Particularly strongly developed are the limestones in the valley of the Sutschan, where they have been followed up for a distance of 45 versts (to the village of Frolowka), and from them is derived an interesting find—a beautifully preserved specimen of *Richthofenia lawrenciana*, de Koninck. According to Margaritow's statement the same limestones crop out on the right bank of the river Schite-chä. A similar limestone has been brought back by Iwanow labelled "Anutschino am Fl. Daubi-chä. Kalkstein-Schlucht," and in it occur valves of *Productus Purdoni*, Dav., and of a *Marginifera* which is very like *M. typica*, Waag. On the west coast of the Amur bay, near a place called Koreiskiye Myssy, there has been found on a coast terrace a piece of black limestone which enclosed *Lyttonia tenuis*, Waag., *Spiriferina cristata*, Schloth., *Thamniscus timanicus*, Stuck., and other less satisfactorily preserved *Bryozoa*. An entirely similar limestone crops out on both banks of the river Mangutai about 20 versts above the point where it falls into the Amur bay. According to Iwanow the limestone has here a thickness of 120 meters, and notwithstanding its appearance, somewhat differing from that of the limestones of the Tawaisa bay and of the river Mai-chä, it harbours the same conspicuous *Fusulinæ* in company with the same brachiopod fauna: *Camarophoria Margaritovi*, mihi, *Spiriferella saranæ*, Vern., *Spiriferella Keilhavii*, Buch, *Spirifer Haidmani*, Foord, *Productus porrectus*, Kut., *Pr. Weyprechti*, Toula. From this it follows that we are not yet in possession of definite stratigraphical data to guide us in the settling of the relationship of the limestones which crop out sporadically in the southern parts of the Ussuri region, but that their palæontological character remains pretty uniform all over the territory explored by Iwanow, and consequently we may, without incurring any serious risk, ascribe to them, at least provisionally, the same age. On the whole 27 brachiopods have been reported from the above-mentioned limestones of the Ussuri region, of which 16 are identical with inhabitants of the Schwagerina horizon of the Ural and Timan. Comparing our fauna with the one described by Waagen from the Salt Range, we find that 6 species are common to

the Amb beds, 6 to the Katta beds, 11 to the Virgal beds, 9 to the Kálabágh beds, 7 to the Khund Ghat beds, 5 to the Jabi beds, and 2 to the Chideru beds. From this comparison we can hardly arrive at any other conclusion than that the fauna of the South Ussuri region corresponds in age on the one hand to the Schwagerina strata of Eastern Russia, and, on the other hand, to the Virgal beds and perhaps partly to the Kálabágh beds of India. It is interesting to note that all those species which give our fauna its peculiar features (*Lyttonia tenuis, Hemiptychina inflata, Marginifera typica, Richthofenia lawrenciana*) belong to the number of those which occur either exclusively or at least mainly in the beds of the Salt Range referred to above.

Hence the fauna of the South Ussuri limestones furnishes us with a further proof that the Schwagerina deposits in the east of Russia are in no case older than the Virgal beds of the Salt Range. Besides the limestones referred to, there are found in the collection of Iwanow ash-grey calcareous sandstones, which crop out between Chatunitschi and Mnogau-dobnaja and which are palæontologically only ill-characterized, since the fossils found in them are mostly cores. With certainty have been only determined *Productus Purdoni*, Waag., *Spirifer fasciger*, Keys., and *Productus* aff. *subquadrato*, Morris. I do not know in what relation these sandstones stand to the limestones. It is, however, not impossible that they overlie the limestones and that they correspond to the Artinskian sediments of Russia.

A great resemblance to the Upper Palæozoic sediments of the Southern Ussuri region can apparently be traced in the corresponding strata of Japan. Unfortunately the available data are at present very scanty. It is known that the strata crop out for about 8 degrees along the meridian; and as regards their composition we notice a short remark of Gotsche's, who states that at the basis there lies a white crystalline limestone with wollastonite; this is covered by breccias with crinoid stalks, followed by a ferruginous limestone, which is overlaid by grey limestones with crinoid stalks and *Fusulinæ*. Higher up follows a grey limestone without crinoid stalks but with *Fusulinæ*, and finally the whole is capped with a dark limestone with large *Schwagerinæ*. These palæontological data communicated by Gotsche are very scanty and do not supply us with definite clues. Of greater interest are in this respect the discoveries made by Japanese

geologists, about which, however, only little has yet been published, but among the little is still something which is capable of supplying us with definite hints with respect to the age of the Palæozoics of Japan.

It is particularly a paper by Yabe[1] which deserves notice and in which he describes two *Lyttoniæ* found in the mountainous district of Kitakami in the province of Rikuzen. The author believes the specimen which he discovered in the slates of Matsukawa near Kezennuma to belong to a new species, *Lyttonia* sp. nov., whilst he names the one from the calcareous sandstones near Yakejima *Lyttonia* cf. *nobilis*, Waagen. According to the statements of Jimbo the sandstones of Yakejima enclose besides *Lyttonia* cf. *nobilis* and numerous other brachiopods also remains of crinoids, and rest on the limestones of Kobama, in which the caudal shield of a *Phillipsia* was found, which resembles those discovered in the clay-slates of Maiya in the province of Rikuzen. These slates immediately overlie limestones with *Schwagerinæ* and *Fusulinæ*. Yabe draws therefrom correctly the conclusion that the calcareous sandstones of Yakejima are somewhat younger than the limestones, and he places them in line with the middle Productus limestone of India. According to my own opinion, this correlation could be rendered still more definite if we declare the sandstones of Yakejima, which in all probability correspond to the Artinskian deposits, to be equivalents of the Kálabágh or the Khund Ghat beds and the Schwagerina limestones, similarly to the Southern Ussuri limestones, as homataxial with the Virgal beds. It is highly probable that the sandstones in the southern Ussuri region, with which we dealt above, correspond in age to those of Yakejima. However that may be, there is one fact of great geological significance which cannot be abolished, and that is the remarkable resemblance which exists, notwithstanding the vast distances, between the Upper Palæozoic sediments of Eastern and Northern Russia on one side of Eurasia and those of both the coasts of the Sea of Japan on the other side.

Concluding Remarks.[2]

In the preceding summary it has been demonstrated with sufficient clearness that the type of the Upper Carboniferous Fauna of

[1] H. Yabe. The Brachiopod Lyttonia from Rikusen province. Journ. Geol. Soc. of Tōkyō, Vol. VII, No. 79 (1890).

[2] (Pages 740—742.)

Russia repeats itself within the vast area which comprises the Polar Region, North and South America, India, Central Asia, China, the Indian Archipelago, the Southern Ussuri region, and Japan. In a similar manner the type of the Russian Fauna is met with in the sediments which are homotaxial with the Artinskian horizon and which occur in the Mediterranian region (Trogkofel, Neumarktl, Sicily, the Pyrenees), in the Salt Range and the Himalayas, in quite a number of localities in Central Asia, in Japan, in North America (Texas), and in Western Australia. Notwithstanding the existence of various differences in the character of the contemporaneous faunas, these differences find their explanation not so much in a difference of age, as in differences in the facies of the respective faunas or in local causes.

I have endeavoured to show that the *Brachiopoda* are not without value for the determination of the age of the various numbers of the Upper Palæozoics, and that the peculiar features of the latter, which it is possible to establish by a study of their brachiopods, go hand in hand with the characters which can be observed in other classes of invertebrates in connection with definite geological moments. Without again referring to the whole of the facts which have been dealt with before, I draw attention only to the discovery, made quite lately in various parts of the globe (Russia, North America, India, Japan, and Australia), of representatives of such a remarkable organism as *Helicoprion*, which unquestionably characterizes a very definite moment in the history of the Earth. All these finds have been made in deposits which from their invertebrate fauna we have grounds to consider as homotaxial with the Russian Artinskian sediments.

Starting from this conception of the character of the Upper Palæozoic fauna and of its universal type, we may draw for ourselves the following general picture of the distribution of land and sea during the Upper Carboniferous epoch. The commencement of this epoch is marked by a retreat of the sea from the greater part of Western Europe (except the Mediterranean region), from the eastern flanks of the Ural and the northern coast of North-East Siberia. The Russian sea, which at the same time contracted within the boundaries of Russia, formed part of the extensive Arctic Ocean which, as may be assumed, washed the shores of Greenland and the northern parts of the American Archipelago. In the south, on the

side of the Black Sea, it communicated with the Mediterranean, at least during the second half of this epoch, and towards the south-east it had maintained its connection with the extensive Chino-Malayan sea which had already been in existence during the Middle and Lower Carboniferous epochs. We have even grounds for surmising that the Chino-Malayan sea communicated in the west with the Mediterranean across the present Irān and Armenia. The great likeness of the Upper Carboniferous fauna of Russia with that of South America can hardly be explained by supposing the former to have penetrated to the regions of the Amazon river, to Peru and Bolivia in a roundabout fashion by way of the Arctic Ocean. It is, indeed, very probable that Fr. Frech is right when he contends that the Mediterranean has extended westwards up to the Eastern boundaries of the American continent of to-day.

Towards the close of the Upper Carboniferous period the invasion by the sea of the area occupied at the present day by continents had reached its maximum, and during the following Artinskian epoch the sea commenced to retreat.[1] Still more pronounced is this change at the commencement of the epoch during which the Permian sediments of Russia were deposited, and towards the end of the Permian period we notice undoubted instances of marine invasion only within a limited area of the present continents (in Russia and West Europe, and perhaps in the Polar regions and the western parts of North America) whilst the larger portion of the sediments laid down during the Permian Period is, as far as known, of continental origin.

In my treatise I have also discussed the boulder beds of the Salt Range and of Australia,[2] and the results at which I have arrived in this respect harmonise in the best possible manner with the remark of Ed. Suess[3] with which he concludes his general discussion of the Carboniferous sediments of Central Asia: "Accordingly the whole of the deposition of the boulders which can be observed all round

[1] In some places, for instance on the northern coast of the Chino-Malayan sea, the latter advanced, as is testified by the discoveries of D. Klemenz in the Dsungarian Gobi (Verhandl. d. Russ Kais. Min. Ges. Bd. XXXVIII, Prot. S. 44-45).

[2] When I speak of boulder beds, I understand by them only those which belong to the lower marine series of New South Wales and the corresponding strata of Victoria. In Australia glaciation set in repeatedly during upper palæozoic times.

[3] E. Suess, Beitr. zur. Stratigraphie Central Asiens, S. 11 (439).

the Indian Ocean in South Africa, India, and Australia took place during the Carboniferous Period." Possibly it would not be rash to place with Feistmantel the horizon of the boulder beds somewhere near the boundary between Lower and Middle Divisions of the Carboniferous System.

NOTE ON THE GLACIATION AND HISTORY OF THE SIND VALLEY, KASHMIR.

By R. D. OLDHAM, A.R.S.M., F.G.S., *late Superintendent, Geological Survey of India.* (With plates 11—16.)

The first twelve miles of the Sind Valley, from its entrance to the neighbourhood of Kangan, is straight and open, the ends of all the spurs being truncated along a fairly straight line. This feature has been regarded as characteristic of glacier action, but it is also produced by streams when they are flowing at or near the slope of equilibrium, and have consequently little or no tendency to deepen their valleys; in these circumstances lateral erosion sets in, and the ends of the spurs are gradually truncated where they project into the belt over which the windings of the stream tend to make it wander.

In the case of the Sind valley glacial action is excluded, for this lower part is filled, to a depth of some 300 feet, by stream deposits, the greater part consisting of fine-grained alluvium. This has been cut into terraces by the river, and the terraces, like the existing stream bed, are covered by waterworn boulders. It is difficult to believe that a glacier could have flowed over this deposit, nor is there any sign of one having done so, and it is equally inconceivable that this deposit, which is a continuation of the karewahs of Kashmir, could have been formed and again eroded since the retreat of the glaciers.

Above Kangan the valley begins to narrow, and accumulations of rock-fragments, some of large size, are seen in places, lying on the fine-grained alluvium. These might be taken for moraines, but, on examination, they appeared to me to be in every case accumulations formed by torrents issuing from a narrow side valley in their neighbourhood.

At the junction of the tributary, between Haru and Sambal, there is a great accumulation of débris, much of it large and sub-angular, which may well be moraine material, but may equally be due to occasional floods from the narrow and steep-sided valley of the tributary.

Above the bridge at Sambal the road runs at first over a deposit of rounded and waterworn boulders, but soon enters one composed of angular or slightly rounded fragments of rock, among which limestone fragments occur in an abundance and of a size which is difficult to attribute to the stream of the Sind river. There is consequently a suggestion of glacial action, but the surface conformation is that of a

series of fans, issuing from the side valleys. If, then, the material in the valley is to any extent moraine, the original surface has been completely obliterated by the main and tributary streams of the Sind, while there has also been a large admixture of local débris brought down from the hills to the north.

In this connection may be mentioned an instructive instance showing the care which must be exercised in assuming glacial action without the strongest evidence. About a mile above the Sambal bridge the road crosses a small ridge, composed of angular rock-fragments of all sizes, which presents many of the characteristics of a moraine. A closer examination of the ground shows that it is not one, for on either side of the ridge there is a drop from a higher to a lower level; the line of this drop takes a regular curve, and the ground at its foot is palpably an old river terrace. In the centre of this curve issues the valley of the tributary flowing past the village of Boorphrar, as marked on the map, and the ridge referred to above is composed of the flood deposits of this torrent, among which are sub-angular blocks of 20 feet in diameter. This deposit is now being cut into by the stream, which is crossed immediately after the ridge is passed, and so a comparatively narrow ridge, steep on both sides, has been formed.

So far no very certain or definite signs of glacier action were seen, but it is right to say that I was not expecting to see any, and did not make a close search. In the stretch of the valley next entered, which extends from about a mile below to about two miles above Gund, the evidence of glaciation is striking and abundant. About a mile below Gund the Sind passes through a short rocky gorge, cut through a spur whose top is rounded and scored and grooved in a manner which is unmistakably the result of glacier action. On the left bank of the Sind this spur is covered on the top- and the down-stream side with moraine of the type known as ground-moraine.

A part of the village of Gund is built on a great *roche moutonnée*, and the hillside is smoothed and striated for a height of about 500 feet above the bottom of the valley, the glacier having probably reached another hundred feet above this level. It must be noted that the weathering of exposed rock-surfaces is evidently a rapid process in these regions, and the smoothed and striated surface, once cleared of its protecting layer of soil, is very soon destroyed, principally by the action of frost in opening the joints which traverse the rock, and so causing it to break away in small fragments.

The tributary valley which joins the Sind at Gund is a deep-cut, precipitous-sided gorge whose form is evidently due to the erosion of the stream it carries, but on climbing the hillside, and entering this valley at a height of about 400 feet above the village, where it is more open, the spurs are found to show a smoothing and striation, due to a glacier which issued from the valley. We have, in fact, an older open valley once filled by a glacier, in which a narrow rocky gorge has been cut since it was freed from ice; remains of this older valley can be traced, though obscurely, up both branches of the tributary, but the original surface form has been almost entirely obliterated by erosion.

Above Gund signs of glaciation, in the shape of smoothed and striated surfaces, are numerous for a couple of miles, till the road climbs on to a rocky spur, whose end has been scarped by the river and whose upper surface is smoothed and striated in the most typical manner. From this spur an excellent view of the valley is obtained, exhibiting all the features which have been recognised as due to the action of glaciers. There is the broad, open floor, from which numerous *roches moutonnées* rise, and on the right or north side of the valley the rock walls rise steeply to a height of about 600 feet above the river, and the steep, often perpendicular, walls still show, in many places, the smoothing due to ice. From the top of this steep wall the hillside slopes back at an angle due to weathering, and not at that due to the erosion of a glacier.[1]

The opposite side of the valley does not show this so well, but there are two good reasons for the difference. In the first place, being the south side of the valley, and having a northerly aspect, it is still covered with a dense forest which hides, to a large extent, the minor surface features, while the opposite side of the valley, facing south, is almost devoid of trees. In the second place, the valley is not straight,

[1] As the capacity of a glacier to give rise to a distinctive valley section has been doubted, it may be mentioned that in the north-west Himalayas, where valleys due to river erosion pure and simple are found side by side with those which have carried a glacier, the trough-shaped section of the lower part of the latter corresponding to the portion formerly filled by the glacier is very conspicuous in contrast to the absence of such in the former. This statement requires the qualification that the trough form is only seen where the conditions for its preservation are favourable; being an essentially unstable form, once the glacier is removed, it is only preserved where cut in a rock not liable to rapid disintegration, and where the conditions of the stream which succeeded the glacier have been such that the glacier valley form has neither been obliterated by deposition nor destroyed by erosion.

but bends round an open curve, and the north is the outer or convex side of this curve; it is against this side of the valley that the greatest force of the ice would be exerted and its greatest effect produced.

The trough-shaped valley can be traced to near the Sambal bridge, below which it becomes indistinct, and as this is the first place where moraine material was first recognised with any degree of probability, we may conclude that the Sind valley once held a glacier which extended at least as far down stream as Sambal.

The preservation of the surface forms produced by the old glacier is to be attributed in part to the nature of the rock near Gund, this being a hard, schistose slate, very quartzose in places, and in others distinctly hornblendic, but to a larger extent it is due to the fact that the changes of level which have taken place since the retreat of the glacier happen to have left this stretch of valley comparatively unaffected. Consequently, the old glacier floor has neither been buried beneath stream deposits, nor has the river obliterated the marks of glaciation by cutting a deep gorge out of the old valley.

As Rewil village is approached the valley becomes filled with stream deposits, and no more *roches moutonnées* are seen rising from it; the northern side still rises steeply and the steep face shows, in places, signs of glaciation. These are seen conspicuously on the bridle-path which leads along the hillside between Kulan and Gagangir, and the trough shape of the lower part of the valley can be recognised as far as that village.

At Gagangir the slates give place to limestone, forming a narrow band, separated from the main mass of limestone to the north by a ridge composed of altered volcanic rocks, in the manner indicated in Mr. Lydekker's map. This ridge of volcanics forms a barrier across the continuation of the Sind valley, which not only makes a bend in its general direction at this place, but also changes in form and character. On the west side of the Song valley, joining the Sind just above Gagargir, the limestone ridge rises with a smooth and somewhat rounded surface, which looks as if it might have been smoothed by a mighty glacier coming down the main valley. As the Song valley itself is a narrow, steep-sided and irregular gorge, evidently formed by stream erosion, and unaffected in its form by ice, and as the smooth surface referred to is so steep as to be quite inaccessible, it is more probably due to a fault surface, from which the overlying rock has come away in a landslip.

However this may be, the outer end of this spur does seem to have been rounded by ice, and a little further up the main valley there is what appears to be part of an old glacial floor, now cut into by the river, which flows in a rocky, vertical-sided gorge. Above this, little more than a mile from the village of Gagangir, no trace of glaciation can be seen; the valley narrows in and the river flows in a rocky gorge, cut at first along the boundary between the volcanics and the limestone, but afterwards turning across the strike and penetrating the high range formed by the volcanics in a narrow and precipitous-sided gorge, through which the river runs in a succession of small waterfalls and foaming rapids.

At its upper end the gorge ceases suddenly and the road enters a valley, on one side of which rise hills composed of limestone with its associated shales and quartzite; on the other side a steep slope, composed throughout of moraine material, rises to a height of 500 feet, and beyond can be seen a broad and open valley, more like the lower part of the Sind valley and quite unlike the gorge just passed through.

The nature of this gorge is unmistakable; it is not only a river-cut gorge, showing no signs of ever having carried a glacier, but it is a gorge which the river is evidently still engaged in deepening. When I first passed through it, I was inclined to attribute its presence, between two more open parts of the valley, both of which retain, in greater or less degree, traces of having once carried a glacier, to a recent elevation of this part of the Sind valley, and to a consequent cutting down of the bed of the river, with a concomitant obliteration of the traces of glacial action. As will be seen in the sequel, this hypothesis proved untenable, but the fact remains that the band of volcanic rocks, which crosses the Sind at this place, is a zone of special structural elevation. The map and section published by Mr. Lydekker are enough to prove this, and whether his interpretation of the section, as a fold, or whether the alternative explanation of the presence of the volcanics by faulting, be accepted, in either case the line along which they occur must have undergone a greater amount of elevation than the limestones on either side.

There is also evidence that part of this elevation is of very recent date, if it be not still in progress. Just above the first or lower bridge at Sonamarg there is a terrace, whose upper surface has an elevation of about 50 feet above the present river bed. It is composed throughout of well water-worn pebbles and boulders of the same average size, and

the fact that the deposit extends down to the level of the stream shows that, before it was formed, the gorge must have been cut down to at least its present level, that elevation then took place at a greater rate than the downward erosion of the river could keep pace with, and that afterwards the elevation either ceased, or became slower, and the river, being once more able to lower the barrier across its path, cut down into its old deposits.

To the left or east of the river rise the old moraines on which the summer settlement of Sonamarg is situated, whose description it will be convenient to defer for the present, while continuing that of the main valley of the Sind. Crossing the lower bridge, the road traverses the outer fringe of the Sonamarg moraines, between which and the village of Sonamarg is a broad plain of river gravels, some 30 to 40 feet above the present level of the river and, apparently, a continuation of the terrace already mentioned.

On the opposite (north) bank of the river, deposits of a very different character are exposed in section; they consist of fine gravel, are distinctly and thinly bedded, and the beds, though practically horizontal, have a perceptible, though very small, upstream dip. These deposits are indurated, while the coarser river gravels on the opposite side are still loose; they are evidently the older of the two and, from their nature, must have been deposited, either in a shallow lake, or in a stretch of the river where, from one cause or another, the gradient had been reduced till the stream was no longer able to transport anything coarser than fine gravel.

Just above the bridge and opposite the village of Sonamarg, the river has cut into a low, round-topped spur of rock, whose upper surface has a form suggesting that it had been rounded by ice, though it is too weathered to preserve any striæ. A little higher up a spur comes down from the other side, and the valley, as a whole, is narrower here than it is below or above.

Proceeding up the valley, this preserves its open character and general straightness, but beyond this there is no certain sign of its having carried a glacier. Just below Viligrar are a series of moraines, evidently formed by a glacier which issued from the Viligrar valley; on the other side of this valley moraines can also be traced, though not so distinctly, yet the valley itself is a typical river-cut gorge with vertical sides, in every respect except in the absence of interlocking spurs. The absence of signs of glaciation in this side valley, in the face of the

evidence that it carried a glacier at a later date than the main valley, renders the absence of definite signs of glaciation in the latter easily intelligible, and shows how little the thin-bedded limestones of these hills is adapted to preserving the effect of a glacier.

From the next side-valley, that of Kokuron, there issues a great barrier running out into the valley: no distinct lateral moraines can be seen, but the uneven surface and the angular nature of the débris of which it is composed, suggest that this may be a moraine, though the possibility of its being an accumulation of flood deposits is not excluded.

Talus fans are common all along the sides of the valley from Sonamarg on, and above Kokuron they become almost continuous on the right, or northern, side. A section disclosed by the stream at Ranga shows that some of the slopes which look like talus are not so in reality, but due to a sloping-off of the solid rock and the forming of an even slope, thinly covered by débris, which may be distinguished as pseudo-talus.

As Baltal is approached the character of the valley changes once more, being bounded by the lofty cliffs (*bal*) from which Baltal derives its name. Here the straight and open valley which has been followed, comes to an end, the direction of the main valley takes a bend to the right, and at the bend it is joined by the tributary up whose valley runs the road over the Zoji-la.

Taking the main valley first, this is open and filled at the bottom with débris, and bounded on both sides by lofty cliffs of bare rock. The stream now flows at the foot of those on the left, or western, side of the valley, and these are consequently the steepest, show the most freshly exposed surface, and are least cut into by tributary ravines. It is evident, however, that the stream at one time cut at the base of the cliffs opposite, and has been forced away from them by the increasing amount of débris which fell from them. In time the process will doubtless be reversed, and the increasing amount of material falling from the increasingly lofty cliffs on the left bank will force the river over to the opposite side of the valley.

The open valley only extends for a little over a mile from the Baltal rest-house, the valley then bifurcates and each of the two tributary valleys immediately becomes a precipitous-sided rocky gorge. I ascended that along which there is a track leading to Amarnath; in ordinary years it is said to be impassable, but this year, on account of the

unusually large snowfall, it was possible to make one's way up the gorge, over the unmelted snow which bridged the stream. The ascent is a rapid one for about 3 miles, in which the rise was 2,000 feet by a not very trustworthy aneroid, and certainly not less than that. At this level the valley becomes more open, and it was possible to see up it for a couple of miles further, but even here there was a narrow, rocky and winding snow-filled gorge, of unknown depth, cut in the older, open valley.

Looking back out of this valley, from near the confluence, the bare cliffs bounding the opposite side of the valley are seen to be crowned by the grassy slopes of the Rainur grazing grounds, and from one of the small valleys draining these slopes the stream falls to the Sind in a series of waterfalls which have a height of over 2,500 feet.

Here there is no longer any trace of glacier action in the valley; whether it ever carried a glacier or not, its present form is due to the action of the river alone, and, whatever may be the cause, the river is evidently still deepening its valley above Baltal, while the two separate streams above the confluence are still more actively deepening their channels, and have not yet reached that stage, attained by their combined waters, when they can commence to erode laterally and widen their valleys.

At Baltal the main valley is joined by the tributary up which runs the road over the Zoji-la, and at once a very different type of valley is met with. Narrow and steep sided, the view up it is blocked by a precipitous spur running down from right to left, and immediately behind this another, equally precipitous, runs from left to right, along whose face runs the track, dignified by the name of a road, by which the traffic over the Zoji-la is carried. This is a typical river gorge, and on entering the valley its character is still more clearly developed, as a narrow, precipitous-sided and winding gorge, in active process of erosion by the stream it carries.

The ascent from Baltal is very steep to the crest of the spur mentioned above, which is regarded as the crest of the pass, though the summit level, on the watershed, is some two miles further on. From the crest of this spur an open and tolerably straight valley stretches to the north-east, but in the floor of this valley is excavated a narrow, almost vertical-sided, gorge, the upper course of the stream which flows to Baltal. This gorge continues to the junction of the Kanipater stream, and up the valley of that tributary; it probably extends a little

way further up the main valley, diminishing in depth, but cannot reach very far, for in the gaps which had melted through the snow, I could see that the stream flowed over a flat and gravelly bed, having a gentle gradient.

The valley here is, once more, of the glacier-shaped type, with a broad floor; steep sides showing glacial smoothing rise from this floor, the valley sides sloping back from the level of the old glacier surface and the minor tributaries entering by waterfalls.

The actual watershed is determined by a fan of débris, coming down from the mountains to the north-west, and beyond it the valley continues of the same type and appearance, with the sole difference that the waters are flowing north-east instead of south-west.

The evidence of "capture" is very distinct; not only have we the absence of any defined watershed, and the continuance across the present watershed of a valley form due to streams and glaciers which once flowed from the south-west, but there is the palpable disparity between the size of the valley and the stream it carries on the one hand, and the signs of recent and rapid erosion on the other. The Sind drainage is evidently cutting back into that of the Gumber, but it must be admitted that the site of the watershed seems to be determined by some other cause. For a mile on the Sind valley side there is no sign of erosion, the stream flows over a flat of débris, and at one place it is interrupted by a small lake, or rather pool; moreover, the descent from the watershed, though gentle, is distinctly steeper on the side of the Gumber than on that of the Sind valley. From these facts it seems probable that the position of the watershed has been determined by earth-movements and the raising of a barrier across the valley which once drained into the Gumber, and it is important to note that the site of the present watershed lies very near the axis of the anticline of older slates, which separates the permo-triassic limestones of the Sind from those of the Gumber valley.

The important question of the date and extent of the changes which have taken place in the distribution of the drainage will be considered further on, after this description of the Gumber valley.

At Mechoi a glacier comes down to about half a mile from the road, and has evidently extended almost down to where the road now runs, as is shown by the heaps of moraine material, still bare of any vegetation, which lie scattered over a glaciated rock-surface. The tongue of this glacier lies in a comparatively narrow and somewhat

V-shaped trough of rock, whose sides are smoothed and striated, but below the end of the glacier the valley, as a whole, is seen to have a tolerably flat rock floor, and in this floor is a narrow depression which continues up into the hollow occupied by the glacier. The present state of the glacier is one of retreat from its original extension, as is shown by the lofty lateral moraines between which it lies, but it seems as if there had been an even more complete retreat of the glacier than at present during which a stream gorge had been cut in the more open glacial valley, and that this gorge had afterwards been occupied and partly modified in form by the glacier, when it once more advanced. This supposition is supported by the character of the main valley below Mechoi.

Immediately below the Mechoi valley there are no less than eight distinctly marked ridges, radiating into the main valley, and representing old lateral moraines of the Mechoi glacier. On the opposite (up-stream) side of its valley no moraines are seen, except some small remnants clinging to the hillside, and it is probable that this is due to their having been removed by the action of the stream, which is here forced over to the right or southern side of the valley by a great talus fan coming down from the opposite hills.

The moraines just mentioned are truncated at their further end by the stream, which is cutting its bed downwards, and the extension of the Mechoi glacier across the main valley, which they indicate, must have held back the downward erosion of the valley above it. There is indication of a temporary lake having been formed, in some very false bedded deposits of fine gravel, which are exposed in section on the left bank of the river, opposite Mechoi.

Below Mechoi the Gumber valley assumes a very different aspect to that of its upper portion. There is, first, a broad, open valley, whose floor is marked by the rounded tops of spurs, which stretch out from the steeply rising hills on either side; and secondly, cut into this more open valley, is a narrow, winding valley, with steep sides, in which the river flows. Here the broad, open valley, which continues on much the same general slope as that of the valley above Mechoi, may be regarded as the glacier valley at the time of the greatest extension of the glaciers, and the narrow, winding valley as having been formed by the river, after the retreat of the glacier.

This, however, is not all. It will be seen from the map that the Vachkarya and Gumber streams flow parallel to each other for over a

mile above their junction; in other respects the map somewhat misrepresents the facts, for the two streams are not separated by a high ridge, but by a low and narrow spur, not over 200 feet in height, while the Vachkarya stream flows through a broad, grassy plain, known as Minimarg. The road crosses the spur referred to over moraine material, and enters the Vachkarya valley, which, in spite of the smaller size of the stream it carries, is larger and broader than that of the Gumber on the other side of the spur.

There is here a diversion of drainage, the continuation of the deep-cut valley of the Gumber below Mechoi is through a gap, now filled with moraine, at the head of the Minimarg plain, and the history of what has taken place seems to be as follows:—First, we have a valley, occupied by a glacier for long enough to allow of its impressing the peculiar features due to its action on the valley; this valley, as left by the glacier, was open and comparatively flat-bottomed, the bed level being about the tops of the spurs now projecting into the valley. Then came a general retreat of the glaciers, and river erosion set in, cutting a gorge in the bottom of the trough left by the glacier; next the glaciers advanced once more, as is shown by the smoothing and striation of the sides of the deepened valley, but not for long enough to materially alter the form and destroy the traces of stream action in it.

This narrow, deepened valley was joined by that of the Vachkarya, near the head of what is now the plain of Minimarg, and, as the glaciers retreated, that of the main valley retreated faster than that of the tributary, or, perhaps, after the retreat there was a fresh advance, during which the Vachkarya glacier filled the main valley with its lateral moraine and forced the stream of the Gumber to take the course it now follows. So it comes to pass that the Vachkarya occupies the valley which once carried the waters of the Gumber and its own, while the main river has been forced to cut for itself a narrow, rocky gorge and to find its way back into the main valley along what was originally part of the course of a tributary.

The Vachkarya valley, which has been mentioned above, is a deep and narrow, rocky valley, whose sides have been smoothed and striated by a glacier. Looking up this from the junction with what is, as has been explained, really the valley of the Gumber, the view is soon obstructed; but the bend of the valley, round the spur obstructing the view, is gentle, and above this the valley combines the general

straightness and gentle curves of a typical glacier valley, with the general V-shapes of one eroded by water. There is a tendency to a U-shape at the bottom, below which is a purely river-formed rocky gorge, whose cliffs vary from 10 to 30 feet in height.

A noteworthy point about this valley is that the tributary valleys all enter it at a height of 200 feet or so above the bottom of the valley, and, whether this overdeepening of the main valley is due to ice or water, there can be no doubt that the lower part of the valley has been occupied by a glacier, for its sides show the smoothing and striation characteristic of that agent.

The most probable explanation of the form of the valley is that this is mainly due to the action of water, and that the stream-formed gorge has been partially modified by a glacier, which did not last for long enough to convert the valley into the typical glacier form. It has already been shown that the original Gumber valley, as left by the glacier after the retreat from its maximum extension, was deepened by river erosion; this would lower the outlet of the Vachkarya valley and set up downward erosion in it, but, on account of the smaller volume of its stream it might well have failed to reach that stage at which a stream commences to widen its valley, before the glacier once more advanced and filled the stream-cut valley, rounding off the projecting angles of the spurs and straightening the general course, without having time to obliterate the general features of the valley, before it again retreated. It may be noticed in this connection that the upper part of the valley, which must have been longest under ice, shows a more perfect approach to the typical glacier form than the lower, and that in the lower valley there are still indications of an older, more open and trough-shaped valley graded to the level of the oldest glacier valley of the Gumber.

The lowering of the base level of the Vachkarya has enabled it to extend its drainage area; it is probable that this has taken place in more than one direction, but the only one actually seen by me is its capture of a part of the Mechoi drainage. Not far above the point where the Vachkarya enters the Minimarg plain, there is a tributary valley, or ravine, entering on its left, or western side, in which is a small hanging glacier with a very large moraine. This ravine has cut back part of the ridge bounding the Mechoi drainage area, whose glacier now overhangs the watershed. It is very probable that the removal of the hills on the eastern flank of the Mechoi glacier is the

explanation of the very marked contrast between the large lateral moraines left by it in the Gumber valley, and the insignificant size of the lateral moraine formed during its last extension.

Below Minimarg the quartzose and hornblendic schistose slates give way to limestone near the junction of the next tributary—that called Kharo on the map. From this on to Matayan the river flows through permo-triassic limestones and associated rocks, and all trace of glaciation of the rocks is lost. The valley is open and steep-sided, but the extensive flats of gravel show that its present form is largely due to lateral erosion by the river, and the only traces left by the glacier which once filled it are the moraines which cling to the hillsides.

Having described the Sind and Gumber valleys and their relation to each other, there still remains for consideration the question of the amount of the increase of the former by capture of the head waters of the latter.

To a certain extent this is obvious. Looking up the valley of the Sind, from the ascent to the Zoji-la, the precipitous sides of the valley are seen to end in the grassy slopes of Harbaguan and Rainur; on these can be seen valleys whose open section, grassy slopes, and comparatively gentle gradients are abruptly truncated by the bare, rocky precipices which descend to the valley of the Sind.

The larger of these valleys has the trough shape characteristic of a glacier valley, and still has a small glacier at its head, while the abrupt truncation of its lower end shows that the valley must formerly have extended to a greater length than at present. The elevation of the valley bottom is distinctly above that of the Zoji-la, and there can be little doubt that the drainage of these elevated valleys flowed into the Gumber before the Sind valley penetrated so far, and diverted into its course the whole of the drainage which now flows past Baltal.

Below Baltal there are no obvious signs of diversion of drainage, and for further evidence of the original extent of the Gumber valley we must return to Sonamarg and its moraines.

Between the two bridges the track, leading to the summer resort of Sonamarg, leaves the road and leads over uneven ground, which can easily be recognised as an old moraine, till it reaches an amphitheatre surrounded by a continuous ridge of lateral and terminal moraines, within which a series of lesser moraines, marking successive stages in the retreat of the glacier, can be seen. The source of the material composing these moraines is not far to seek, for they lie at the mouth

of the Darnar valley, on whose sides small, hanging glaciers can still be seen, while the valley itself shows, in a most typical manner, the straightness, the trough-shaped section, the smoothed and striated sides, and the entry of lateral valleys at a height above the bottom, which are characteristic of valleys that have been shaped by glaciers In the present instance these features are rendered more conspicuous by the fact that the valley has been excavated along a band of comparatively soft, shaly rocks, lying, with vertical bedding, between hard limestone on the one hand and the still harder altered volcanics on the other.

As the Atlas of India is on too small a scale to represent these moraines satisfactorily, I have made a plane-table sketch of their disposition which will serve to illustrate what follows.

The first point to be noticed, and one that is even more striking on the ground than in the plan, is that these moraines must have been formed by a glacier which flowed in the direction which is now up the Sind valley. This is well seen when the moraines are viewed from one of the spurs in the Shokdar valley, when the Sind river can be seen flowing, in its deep-cut valley, from left to right, while behind it the moraines slope down from right to left.

Even more striking is the manner in which the lateral moraines on the left, or south, side of the old glacier stretch right across the entrance of the gorge through the ridge of volcanic rocks. The bed of this gorge, as has been mentioned, lies 500 feet below the crest of the moraines ; moreover, the whole of this depth is cut in moraine material, showing that the valley must have been excavated to its present depth before the glacier began to form its moraines. It is consequently difficult to escape the conclusion that the present gorge of the Sind could not have existed at the time when the glacier extended over Sonamarg, for, had the gorge been then in existence, the glacier would naturally have flowed out in that direction, instead of building up its moraines across the gorge.

This conclusion involves the supposition that the drainage from Sonamarg escaped to the northwards, and as the lowest point on the watershed, in the Zoji-la, has an elevation of about 2,500 feet above the village of Sonamarg, it also involves a change of relative level, of at least this amount, since the formation of the Sonamarg moraines. Large as this elevation may seem, yet, in view of the evidence which exists to show that there have been changes of level in the Himalayan

region in historic times, it is not in itself impossible. I have already mentioned that there appears to be a certain amount of tectonic reversal of drainage on the southern side of the watershed, and in the absence of direct evidence, in that neighbourhood, of the amount of change of levels which has taken place, the hypothesis that this reversal has extended as far as Sonamarg cannot be summarily rejected, and must be examined in greater detail.

The first point to be considered is the fact, indicated by the course of the lateral moraines, that the glacier flowed straight across the mouth, without any part of it flowing down the gorge of the Sind. This shows that the gorge could not then have existed in its present form, but it does not show that the course of the drainage was to the southward, for there has certainly been an elevation of the rock-barrier below Sonamarg, leading to the accumulation of river gravels above it, since the cutting of the deep channel through the moraines, and it is conceivable that before or during their formation there might have been a larger and more rapid elevation of the range to the south, making it easier for the glacier to flow up-stream into the open valley of the Sind, than down its gorge.

It is, however, obvious that if this be the explanation, then the gradient of the river above the gorge must have been diminished, a lake might easily have been formed, and in any case there should be a great accumulation of river deposits up-stream of the rising barrier. Now the Shokdar valley to the west of the Sonamarg has a very different aspect to that of the Darnar valley. Instead of the openness and trough-shaped section of a glacier valley, it is narrow, winding, has a V-shaped section in its lower part, and, moreover, is filled to a great depth by stream gravels, now cut into by the stream which formed them. The absence of signs of a glacier having filled this valley is explained by the lesser elevation of the hills bounding it, and is reflected in the fact that while there are now no glaciers on its slope, the south side of the Darnar valley still shows four small glaciers; it is therefore easy to understand that when the Darnar valley carried a glacier throughout its length, the lower beds of the Shokdar valley were free from ice.

The filling of the Shokdar valley with stream deposits fits in with, and indeed demands, the formation of a barrier in a down-stream direction, and the depth of this filling, being approximately the same as the height of the Sonamarg moraines, is consistent with the idea that this

barrier lay across the gorge, but if we turn to the main valley we find no filling of river deposits, such as would be demanded by this hypothesis. The valley is open, at a lower level than the moraines, and devoid of any trace of the accumulation of river gravels which must inevitably have been formed had a barrier of 500 feet in height been raised across the Sind valley at a time when it possessed anything like its present extent. The features of the valley are consistent with the hypothesis that the Darnar glacier and its moraine formed the barrier that gave rise to the accumulation of stream deposits in the Shokdar valley, but they do not fall in with the alternative hypothesis that the barrier was common to the drainage area of both valleys.

The supposition that the Sind river followed its present course through the hills south of Sonamarg having been excluded, there remains only the alternative hypothesis of a complete reversal of the course of the drainage, an hypothesis which is supported by direct evidence in its favour, in addition to that against its alternative.

Mention has been made of the traces of glacier action on the rocks near Sonamarg village, and of the moraine material there. This moraine consists, so far as the larger blocks are concerned, almost entirely of volcanic rocks; up-stream, beyond the old fort of Abrim Khan, the valley bottom is strewn with large blocks of the same rock, which show signs of having been water-worn, but still retain, to a large extent, the subangular form due to weathering. The river gravels above Sonamarg are full of boulders and pebbles of the same rock, but they get rarer and rarer up-stream.

An inspection of Mr. Lydekker's map shows that the band of volcanics which crosses the Sind below Sonamarg, also crosses the upper waters of the river in Harbagwan; it is, consequently, conceivable that pebbles of this rock might find their way, down the valley, to the neighbourhood of Sonamarg, but it is not conceivable that pebbles derived from this source should grow more abundant, larger in size, and less waterworn in a down-stream direction. The only other source for the fragments of volcanic rock above Sonamarg is the range to the south, and whether they are derived solely from old moraines, or were in part carried by water, their presence involves an easterly flow of the drainage, which now flows west past Sonamarg.

It is possible to determine the precise stage in the history of the formation of the moraines at which the drainage was first directed into its present course. The outer moraines, up to that marked

A B C on the plan, are all breached by a series of gaps, through which a stream still flows, fed by percolation from the moraines, but quite incapable of having formed the valley through which its course to the Sind lies. This valley is comparable to what might be expected from a stream of the volume and power of that which now flows from the Darnar valley, and may safely be attributed to the glacier stream, flowing over and among the moraines and having power to move even large blocks of stone. The moraine which lies across the head of this valley has a low gap at B, and the form of the ground on the outer side of this gap shows that a stream once flowed through it, but a stream of much less power than that which carved its course through the older moraines, for, instead of cutting a channel for itself, it was merely able to spread out the glacier débris in a fan of deposit.

This moraine marks the time when the larger part of the water flowing from the glacier had already been tapped by the Sind valley. It is probable that there was no stream flowing directly from the glacier to the Sind, but this river had cut back, through the rock barrier, into the moraine, and received an increasing proportion of the sub-glacial water of the Darnar glacier, by percolation through the moraine. By the time the glacier had retreated to the limit, which it only held for a short time, marked by the next succeeding moraine the glacier stream seems to have changed its course and flowed to the Sind, for there is low ground and a truncation of the large moraine just south of the point C. The gorge had by this time been fully established, but not cut down to within a couple of hundred feet of its present level. At a later stage the glacier retreated still further, the stream was established in its present course, and has since cut down into the old moraine as the bed of the Sind was lowered.

It will be seen from this that the exceptional perfection in which the moraines have been preserved is directly due to this diversion of drainage, and the consequent drying up of the old glacier stream, which would otherwise have cut its way through them.

Though it is easy enough to determine the exact stage in the formation of the Sonamarg moraines at which the Sind valley captured their drainage, it is not so easy to determine which of the epochs of greater extent of the glaciers they belong to. Evidently not the first and greatest of the three recognised in the Gumber valley, for at that time the glacier must have extended the whole length of the valley, so that the choice remains between the second and third of the epochs of

glaciation. The extension of the glaciers during the second epoch seems to have been much greater, as compared with their present size, than is indicated by the Sonamarg moraines; on the other hand, these represent a greater comparative extension of the glaciers than the moraines which project into the Gumber valley at Mechoi. There are, however, three considerations which must be borne in mind in this connection; firstly, the collecting area in the Darnar is much greater than in the Mechoi valley, and a lowering of the permanent snow-level would cause a comparatively much larger extension of the glaciers; secondly, the Darnar valley has certainly lost some of its area by the cutting back of the Aro valley, and though the amount so lost may be small in comparison to the whole area of the valley, it is large in proportion to the possible collecting ground of the glacier, besides—what is more important—including higher ground than is now found along the watershed; thirdly, the precipitation is greater in the Darnar than in the Mechoi valley, and if the proportion of each which falls as snow were equally increased, there would be a greater extension of the glaciers in the former than in the latter case.

These considerations lessen the weight of the apparently much greater extension of the glacier, and are supported by the fact that there are no well-marked moraines in the Darnar valley which could be ascribed to the third advance of the glaciers, as should be the case if the Sonamarg moraines belonged to the second. It is therefore probable that they were formed during the latest, and least, of the three epochs of greater extension of the glaciers.

Whatever may be the epoch of their formation, it is, geologically speaking, extremely recent, and the facts and considerations detailed above show that within the time which has elapsed since that epoch, the Sind river has lengthened its course by 20 miles and added 150 square miles to its drainage area, while the range to the north of it has undergone an elevation of at least 2,500 feet as compared with the valley at Sonamarg, whose drainage formerly flowed through the valley now forming the Zoji-la.

This is the extreme extent of the changes which can be established with certainty, but there is good reason to suppose that the original extent of the Gumber valley was even greater than that which has been shown. In the first place the valley between Sonamarg and Ranga has undergone little or no change in form since the reversal of its drainage, as is shown by the position and preservation of the

Niligrar moraines, yet in form and size it does not seem to be accounted for by the drainage of the Darnar and Shokdar valleys alone, and so suggests that it may have carried drainage from beyond the hills to the south of those valleys. In the second place, there is the form of the tributary valleys of the Sind; at least as far down-stream as that which joins below Sambal, they have an upper portion, which is open and has a moderate gradient, and a lower, steep, precipitous-sided gorge which leads down to the Sind. This feature might be attributed to the conservative action of the glaciers which certainly filled the upper portions and held back the downward erosion of the valleys, but it is evident that the feature must be in part antecedent to the glaciation of the main valley between Gund and Gagangir, which is most probably attributable to the first great extension of the glaciers, or more doubtfully and at latest to the second.

The feature is in kind, though not in degree, the same as is seen in the Upper Sind, above Baltal, and is very likely due to a similar cause, that is to say, the upper valleys of the tributaries are the remains of old valleys which once drained northwards to the Gumber and have not yet been reached by the retrocession in levels caused by the cutting back of the Sind valley.

EXPLANATION OF THE PHOTOGRAPHS.

PLATE 12.—*Gorge of the Zoji-la.*—The summer track leads over the slopes of the hillside to the left, the winter track over the snowdrifts in the gorge, which is cut in vertically-bedded limestone and slate. The gorge shows the steep sides and interlocking spurs characteristic of a river-cut gorge.

PLATE 13.—*View in the Sind valley above Baltal.*—The cliffs shown in this view are on the left side of the valley and about 2,500 feet high. They mark the cutting-down of the valley bed since the diversion of drainage, and above them are the smoothed, grassy slopes of the original valley, now forming the Rainur grazing ground. This photograph also illustrates the influence of structure on erosion; the streamlet in the centre happens to flow over a synclinal fold, where the limestone has been compacted by compression and has, consequently, been unable to cut back its valley, and falls over a series of waterfalls; to the right of the picture the limestones have been bent into an anticline and a similar stream flows in a ravine which it has cut out of the hillside, thereby obliterating the grassy slopes of the old valley.

PLATE 14.—*General view of the Sonamarg moraines, taken from one of the spurs in the Shokdar valley.*—This shows how the glacier must have flowed from right to left of this picture, while the Sind river now flows from left to right in the valley cut through the moraines.

PLATE 15.—*View of the Shokdar valley, showing the river gravels accumulated in it when the outlet was blocked by the Sonamarg glacier.*—These have now been cut into terraces during the re-excavation of the valley.

PLATE 16.—*The Mechoi glacier.*—Shows the open valley formed by the glacier at its greatest extension, the narrow gorge cut in the floor of this valley during the retreat of the glacier and now filled by the existing glacier. Also the lateral and terminal moraine formed when the glacier had a slightly greater extension than at present.

ON THE OCCURRENCE OF A SPECIES OF HALORITES IN THE TRIAS OF BALUCHISTAN.

By E. VREDENBURG, A.R.C.S., *Deputy Superintendent, Geological Survey of India.* (With plates 17 and 18.)

During the summer of 1901, an interesting specimen of an ammonite belonging to the catenate group of the genus *Halorites* was found in the triassic shales of Balúchistán. The matter was reported in time for insertion in the General Report of the Geological Survey for 1901-02, but it had to be omitted in consequence of the very narrow limits which were then prescribed for that publication.

The surveys of 1901 disclosed an unexpected large development of triassic beds in the highlands situated south of the Upper Zhob Valley. The hills that border the Upper Zhob both to the north and south exhibit great structural complications, and include a vast number of different geological formations. Two of these, however, cover an area far greater than all the others. They are two groups mainly consisting of shales, the Kojak shales of tertiary age, and the triassic shales, situated, respectively, north and south of the valley. These rocks preponderate to such an extent, that in a rapid traverse one is apt to think that they are the only rocks present, as it is easy to overlook all the others, whose outcrops are comparatively small and discontinuous. This explains how it is that, south of the Zhob, some extremely interesting outliers of highly fossiliferous tertiary rocks of eocene and oligocene age compressed into narrow synclines have escaped the attention of previous observers.[1]

The intense pressure to which both the Kojak shales and these triassic rocks have been subjected has induced the development of slaty cleavage, rendering both formations at first sight very much alike. This circumstance, as well as a great paucity of fossils, have misled several observers into looking upon them as identical.

Mr. Griesbach having established the connection of the shales north of the Zhob, through the Toba plateau, with those of the Kojak range whose eocene age he had been able to settle from the presence of

[1] General Report for 1901-1902, page 32.

bands containing nummulites, came to the conclusion that the shales south of the valley also represent the same formation.

Subsequently the hills south of the Zhob were visited by Mr. Oldham. No fossils were met with, but from considerations based upon lithology and stratigraphy Mr. Oldham was led to regard them as triassic, and they are thus represented in the map illustrating the second edition of the Manual of the Geology of India. At the same time, the fossil evidence in connection with the Kojak shales was disregarded, on the supposition that, just as in the triassic area, the nummulitic beds only constituted outliers, and the conclusion arrived at was that the Kojak shales themselves are triassic or upper palæozoic, as is also conspicuously indicated on the same map. Nevertheless, Mr. Oldham expressed some doubt as to the identity of the shales on either side of the Zhob Valley, thus hinting at the true solution of the problem.[1]

On resuming the survey of Balúchistán in 1892, Mr. Griesbach maintained his former opinion that the shales south of the Upper Zhob are the same as the Kojak shales. This time, however, some undoubted triassic and upper palæozoic fossils were found. But as they occurred in loose blocks removed from their original site, an attempt was made to reconcile their presence with the supposed tertiary age of the strata, on the assumption that they might be derived from "blocs exotiques."[2]

The question was finally settled during my survey of 1901 by observing that the triassic fossils are uniformly distributed throughout the whole mass of shales, as mentioned in the General Report for 1901-02. A thorough examination of the rocks, which would have been impracticable during the previous surveys, disclosed some well-marked differences in the lithological characters exhibited respectively by the Kojak shales and the older group. Both, indeed, consist largely of slaty shales, usually of a greenish tinge, but sometimes slate-coloured or of various pink or red tints. In both systems there are numerous intercalations of narrow bands of harder strata standing out on weathering as small ledges or ridges. But while, in the case of the Kojak shales, these harder bands are calcareous sandstones of the same greenish hue as the associated shales, in the triassic beds they are dark compact limestones, nearly black on the fractured surface.

The fossils in the triassic beds are not numerous and belong only

[1] Manual of the Geology of India, 2nd edition, p. 143, footnote. Annual Report for 1901-02, p. 31.

[2] Records, G. S. I., Vol. XXVIII, p. 8. General Report for 1901-02, p. 13.

to a small number of species. By far the least uncommon is a species of *Monotis* closely allied to or identical with *M. salinaria*. The impressions of its thin shells are locally abundant, sometimes coating the entire surface of slabs of shale, whose regular intercalation amidst the surrounding strata can leave no doubt as to their belonging to the formation whose age is thus established. They have been found at numerous places scattered all over the vast outcrop of the shales. Almost anywhere, indeed, a little searching is soon rewarded by the discovery of a few specimens, always of this same species, and, although the fauna is singularly poor, these slates and shales are not quite so barren as the Kojak shales.

These observations dispose of the necessity of regarding the fossiliferous fragments as "blocs exotiques," and it follows that the entire group of shales south of the Upper Zhob is triassic and distinct from the tertiary Kojak shales.

The discovery *in situ* of a specimen of *Halorites* still further confirms these conclusions, and assists in determining the exact age of these rocks. The specimen was obtained in the western portion of the triassic outcrop, where it extends into the Pishin district, near the locality called Mach on the accompanying map, north of a narrow syncline of tertiary rocks which yielded large collections of eocene and oligocene fossils. I noticed that the *Monotis* shells were exceptionally abundant and well preserved at this spot, and after several days of systematic search, I found a single specimen of *Halorites* lying on the surface. It is a species belonging to the group of the *Catenati continui*, and is, so far, the only Indian representative of that group. The spot where it was found consists of rolling ground situated along a rather flat watershed, so that there was no possibility of its having been transported from a distance. It is quite similar in colour and in the constitution of its matrix to the shales which formerly enclosed it.

This is the only ammonite that I ever obtained at the actual spot where it had weathered out of the shales. A few more specimens belonging to other genera, but none so well preserved as the *Halorites*, were picked up from time to time, but always amongst boulders transported along the river beds that traverse the triassic hills. This was also the condition under which Mr. Griesbach discovered the specimen of *Didymites*, described as *Didymites Afghanicus* by E. von Mojsisovics, who from its presence concluded that the Alaunian stage must

be represented in the Zhob district,[1] thus ascribing to the strata that yielded that fossil a later age than to the richly fossiliferous zone of *Halorites* in the Himalayan trias which is regarded by Mojsisovics as belonging to the lower portion of the Juvavian. This geologist drew attention to the remarkable circumstance that the numerous species of the Himalayan beds are all acatenate forms, while strata of the same age in Europe contain catenate forms as well. From these circumstances, and from the presence of catenate species at a higher horizon in the Swearing slates of California, Mojsisovics came to the conclusion that these catenate forms must have migrated gradually in an eastward direction amidst the waters of the Tethys. "As the connection between the Mediterranean Province and the Pacific basin can only have been made by means of the Tethys, the thought occurs to one that the emigration of the catenate *Halorites* to the Pacific basin may have taken place only in the middle or upper Juvavian period."[2]

So far as it goes, the evidence afforded by the single specimen of *Halorites* found in Balúchistán is in harmony with these conclusions. In the Himalaya the horizon of *Monotis salinaria*, which is presumably Alaunian, is newer than that which yielded the numerous specimens of non-catenate *Halorites*. There is good reason, therefore, to conclude that the *Monotis*-bearing shales of Balúchistán are of the same age as the *Monotis salinaria* zone of the Himalaya. The catenate *Halorites* found in Balúchistán is therefore newer than the acatenate specimens of the Himalaya, thus agreeing fully with the theory above referred to.

Considering the great width of their outcrop, the thickness of these shales must be considerable, although it is evident that they are many times repeated by folding. Yet, considering the homogeneity of their scanty fauna, as represented by the single but ubiquitous *Monotis*, one is driven to the conclusion that they represent but one stage of the Trias. This great thickness of shales was probably deposited in a comparatively short time in a rapidly sinking area.

It is interesting to note that in the midst of the triassic area there occurs at one point an outcrop of slates associated with Fusulina limestone. The section is so obscured by close folding, with the development of slaty cleavage, that it is difficult to decide whether this

[1] Pal. Indica, Ser. XV, Vol. III, pp. 44 and 141.
[2] Pal. Indica, Ser. XV, Vol. III, p. 147.

juxtaposition is due to faulting or merely results from unconformity, but the complete absence of strata of intermediate age there, or anywhere near, leads one to infer that whatever may be the structure at that particular place, a stratigraphical break intervenes between the Upper Palæozoic and Upper Trias.

The *Halorites* and a specimen of the *Monotis* are represented on the accompanying plate. These specimens will be described by Prof. Diener, in whose hands they are at present, together with triassic collections from other parts of India.

The small map illustrates the situation of the triassic outcrop. It is compiled from the latest surveys.[1]

[1] In this map the same colour has been used to represent the intrusive rocks of the Deccan trap and the contemporaneous flows or agglomerates of that same formation. The latter are only represented in the neighbourhood of Hamandun, their outcrop is situated on the map north-west of the word "Kushnob."

EXPLANATION OF PLATE 17.

1. *Monotis* cf *salinaria*, Br., from the hill south of Ashna Ghara (Lat 30° 36′, Long 67° 32′) on the road from Pishin to Ziarat.

2. *Halorites* sp., found about one mile south-east of Muhammad Azim (Lat. 30° 38′, Long. 67° 36′).

NOTES ON THE GEOLOGY AND MINERAL RESOURCES OF MAYURBHANJ.[1]

By P. N. BOSE, B.Sc., F.G.S., *late Deputy Superintendent, Geological Survey of India.*

Area examined.

Mayurbhanj has hitherto been a blank on the geological map of India not having been previously examined by any geologist. The State is divisible into a hill-area and a plain-area. Last season (December, 1903, to March, 1904) my work was practically confined to the former, which comprises the Bamanghati and Panchpir sub-divisions, and the western and north-western portions of Mayurbhanj proper—an area of about 2,400 square miles.

Tertiary rocks near Baripada.

As only a very small portion of the plain country has been surveyed, I have but little to say concerning it in this report. There is, however, one matter of great interest which should receive a passing notice. At Molia, two miles south of Baripada (the capital of the State), there are exposed in the bed of the Barabalang river, yellowish and yellowish-brown limestones which are very rich in fossils referable to the genus *Ostræa*. Mr. Pilgrim of the Geological Survey of India who has studied a few specimens which I sent him, has not succeeded in identifying them with any known species of *Ostræa*. He has, however, detected "affinities with Tertiary forms, *viz.*, *Ostræa multicostata*, Deshayes; from the upper part of the eocene of the Paris basin, and *O. Torresi*, Phillipi, from the Magellanian beds of Patagonia which are probably oligocene in age ..... The specimens somewhat resemble an undescribed species of *Ostræa* found in the upper Nári beds of Baluchistan which are probably oligocene in age." Considering that no fossiliferous rocks later than the Gondwanas (except those of subrecent age) have hitherto been known in eastern India in the vast area between Pondicherry and the Khasi hills, the find is of great importance in Indian geology. From what little I have seen of the contiguous district of Midnapur, there is, I think, every possibility

[1] Mayurbhanj, or Morbhanj, one of the States of Orissa, Bengal, lying between 21° 17′ and 22° 34′ lat., and between 85° 42′ and 87° 14′ long.

of fossiliferous strata similar to those of Molia being found there. The Molia limestones pass above into thinly stratified horizontal, or but slightly rolling, greyish white or very pale, green clays. Similar clays are met with in all the sections about Baripada under a variable thickness of laterite averaging about 15 feet.

Hill country: Stratigraphical Summary.

The hill country presents several well-defined ranges, rising occasionally to peaks between three and four thousand feet above the sea-level. It is needless to say that the examination of such a vast area, a large portion of which is covered by thick, almost impenetrable jungle, was of a somewhat cursory character, especially as a good portion of the short season was devoted to the slow work of mineral exploration by diggings.

Throughout the area the sub-metamorphic series appears to be in superposition upon the metamorphic, the latter being exposed by the denudation of the former. The gneiss is at places highly granitoid, and true granite is by no means infrequent. Mica schists with pegmatite veins prevail in the area about Bongarposi in Mayurbhanj proper. The gneissic rocks are much intersected by dykes of basic and intermediate rocks. The principal constituents of the sub-metamorphic series are quartzites, phyllites, and micaceous, talcose, hornblendic and trappean-looking schists. The quartzites are sometimes banded and not unfrequently hæmatitic as well. Conglomerates are rare. The quartzites are occasionally blackish, and dark slaty or subschistose quartzites attain considerable development at places. As in the case of the gneissic rocks, trappean intrusions abound throughout the area. The prevailing strike is north-western, and the dips usually point eastward.

Iron.

The chief mineral wealth of the State consists in its iron-ores, which are possibly among the richest and most extensive in India. In the Bamanghati sub-division, they occur in quantity at the following localities:—

(1) At the foot and along the slopes of the Gurumaishani hill in all directions except the eastern over an area of about eight square miles.

(2) Near Bandgaon in Saranda-pir.

(3) At the foot and along the flanks of the Sulaipat-Badampahar range on the southern border of the Bamanghati sub-division from Kondadera to Jaidhanposi, a distance of some twelve miles.

In the Panchpir sub-division the ores occur at diverse places along the foot of the hills which fringe the Simlipahar range on the western and southern side from Kamdabedi and Kantikna to Thakurmunda, a distance of twenty-five miles.

In Mayurbhanj proper iron-ores occur at several places in the Simlipahar range, as near Gurguria. They were also encountered at places in the submontane tract just adjoining the Simlipahar range on the eastern side—as near Kendua (close to Sorsobila), and at a place two miles west of Baldia.

The ores except when transported occur almost exclusively in the transition series, especially in association with banded hæmatite quartzites. Usually, they consist of hæmatite and limonite. But thick and rather extensive deposits of magnetite were met with at the foot and along the flanks of the Gurumaishani hill, south-east of Kolaisila, east of Sundol, and also near Kotapiti. Magnetite also occurs in quantity near Bandgaon and in the Kondadera-Jaidhanposi area. The average ore in the Bamanghati and Panchpir sub-divisions will probably be found to contain above 60, if not above 65, per cent. of metallic iron.

It is very difficult to make even an approximate estimate of the quantity of available iron-ores. But it would probably be no exaggeration to say, that a practically inexhaustible supply for several furnaces on a modern scale may be safely depended upon. The ores are easily accessible from the Sini-Ghatsila section of the Bengal-Nagpur Railway, and a line of 25 or 30 miles would tap the Gurumaishani area. As will be noticed later on, limestone in the form of tufa occurs at several places in and close to the iron area.

There are a good many families of smelters in the ground described above, and the iron they turn out is held in high estimation by the people. But the furnaces are the smallest and the bellows the least powerful of any I have seen in use anywhere in India. The smelters, therefore, select the softest ores, which are generally very far from the best. When I showed them a few pieces of magnetite, they pronounced these to be mere stones and quite useless as iron-ores!

Red and yellow ochres occur at places and are much used by the Sonthals in painting their houses.

Iron-pyrites occur in some abundance disseminated in talcose and trappean-looking schists in the transition series at places, as at the Mailamghati on the Dhálbhúm border.

Manganese.

Traces of manganese ore were found in laterite close to banded, blackish quartzites near Kuliana in Mayurbhanj proper. I failed, however, to find it in quantity.

Gold.

Gold is washed for in the Subarnarikha river on the northern border of Mayurbhanj proper, and in the Kadkai and Borae rivers in the Bamanghati sub-division. There is nothing specially noteworthy about these river-washings. But, at the head waters of the Borae river about Kudersai and Sapgora there is a tract about 2 square miles in extent, where I found almost the entire alluvium to be more or less auriferous. Some fifty families of goldwashers earn their livelihood by gold-washing in this area. They just scrape off the surface soil which is usually the richest, owing probably, in part, to its being periodically replenished by wash from the adjacent hills during the rainy season, and in part to natural concentration *in situ* by rain water. Nuggets are occasionally met with, but the largest shown to me as found in the area weighed half a tola.

The auriferous alluvium is of a brownish colour, and is thinly spread over micaceous and trappean-looking schists referable to the transition series. I found it to contain more or less gold down to a depth of about two feet. The richest placer deposits were found invariably to occur in the immediate vicinity of dioritic rocks with iron-pyrites traversed by thin irregular veins of quartz. There are no quartz-reefs in the area; and it is a curious fact that, though there are magnificent reefs outside that area, no gold is known to occur either in or near them.

West and north-west of Ruasi and Gohadongri by the Godia river and its feeder, and separated from the Kudersai-Sapgora ground by a low range of hills, there is another area of placer deposits of similar extent. The deposits here are at places 12 to 15 feet in thickness, and consist of rather gritty, brownish, stiff clay resting upon a coarse

gravel bed about 3 feet in thickness. The bed rock seen at places is greyish-white micaceous schist with thin veins of quartz. At one spot (by the Banijbaran stream, a feeder of the Godia) where the alluvium was washed the gravelly layer was found to be the richest. Nuggets weighing as much as 2 to 3 tolas were reported to me as having been recently found in the area under description. It supports some twenty families of gold washers settled in it, besides casual visitors from the Dhálbhúm State.

That the placer deposits described above pay is evidenced by the fact, that they afford an easy means of livelihood to the washers who work with the primitive appliance of a small wooden dish and who are certainly far from remarkable for industry and steady work. Besides, the washers confine their operations to the surface, whereas the entire alluvium was proved to be more or less auriferous; and in one case, at least, the lowermost gravelly layer was found to be the richest. The washers are not aware of this fact; and even if they were they would not take the trouble to dig when scraping the surface serves their purpose.

Whether the deposits would be remunerative if worked on modern methods is a question which can be properly settled only by washing experiments on a larger scale than I was able to make. The best time for such experiments would be the rainy season when there would be a plentiful supply of water.

Mica.

Mica occurs in the following areas:—

(1) In the Bamanghati sub-division about Raibedi and about Tiring. The ground is gneissic and is much intersected by trap-dykes. Mica occurs in nests and strings in pegmatite veins. These were dug into at several places, but the plates obtained were everywhere small, not exceeding 2 or 3 square inches, and the excavations did not warrant the expectation of finding larger ones.

(2) In Mayurbhanj proper mica occurs near Sirsa and in the vicinity of Bangarposi, about Jamgodia and other places. The Jamgodia area appeared to me the most promising. It is composed of mica schists in which pegmatite veins are exposed at places for a considerable distance along the Sankrai river. Muscovite occurs in these veins in good-sized books, but the plates obtained from the surface, though some measured more than 8 square inches, were necessarily in

a much weathered condition. Excavations are in progress to test the quality of the mineral at depth.

Limestone.

The occurrence of limestone in the form of tufa or travertine was noted at the following localities :—

(*a*) Bamanghati sub-division.

1 Rangom hill (near Beter Amda).

2 Asurghati.

3 On the southern side of Gurumaishani hill (between Sandol and Kotapiti).

(*b*) Simlipahar area : Three miles west of Gurguria.

(*c*) Panchpir sub-division : Olkader.

Yellowish fossiliferous limestone occurs in the bed of the Barabalang river at Molia, two miles south of Baripada.

Asbestos, opal, copper-pyrites.

Near Rangom hill, in the Bamanghati sub-division, on the road leading from Beter Amda to Dublabeda, there occurs vein quartz in decomposed epidioritic rocks which affect an exfoliating nodular structure. The quartz veins do not go down deeper than about two or three feet from the surface ; and in them are found opal, actinolite, asbestos and copper-pyrites. Samples sent to Mr. Vredenburg, Curator, Geological Survey of India, are described by him as being " principally opal in which are imbedded well-shaped prisms of a transparent dark-green actinolite passing along the borders of the specimens into fibrous asbestos .... The opal when seen under the microscope is found to have become largely doubly refracting, a considerable portion having been transformed into chalcedony, which is either minutely granular or else arranged into tufts approaching spherulitic structure."

Pottery clay.

The clays which have already been referred to as underlying the laterite about Baripada are generally very well suited for pottery. A sample examined by Mr. Vredenburg, Curator, Geological Survey of India, is pronounced by him to " constitute an excellent material for pottery." Says Mr. Vredenburg : " It disintegrates slowly in water yielding a plastic paste. This I made into a small lump which I burnt

in an ordinary Bunsen flame, heating it to a bright red. It did not fuse, but became intensely hard, and assumed an agreeable terra cotta colour.''

Miscellaneous minerals.

Potstones occur at various places of which the following are noteworthy. They are generally the result of the decomposition of dioritic-looking rocks. But beds of steatite sometimes occur in the transition series :—

(1) In Bamanghati sub-division near Tiring on the Dhálbhúm border.

(2) Three miles west of Gurguria (Simlipahar area).

(3) Nulungi, 5 miles west of Baldia in Mayurbhanj proper. Utensils of sorts are manufactured here which have a ready sale at Baripada.

Grindstones are made at Kuliana (Mayurbhanj proper) out of the quartzites of the transition series.

Agate, flint, jasper, etc., occur in some profusion at places in the Bamanghati sub-division.

MISCELLANEOUS NOTES.

Pyrrhotite from the Kirána Hills, Punjab.

Some interesting specimens have reached the Department from the little known Kirána (Korana) hills of the Jech Doab of the Punjab, which have never been visited by any geologist since their cursory examination by Dr. Fleming, whose account was published in 1854 (in Selections from the Public Correspondence of the Punjab Administration). The specimens here referred to were sent by Mr. F. E. Cole, Assistant Engineer of the Jech-Doab Railway, who obtained them in a railway quarry at Hoondiwala Hill, Kirána Railway Station (under construction). The specimens are large blocks, up to nearly a foot in size, of a compact, homogeneous, jaspideous, semi-translucent quartz-rock of greyish-green colour, through which are scattered numerous masses of pyrrhotite, whose dimensions frequently reach one centimetre or more. The colour of the mineral is brass-yellow. It is distinctly magnetic. It contains neither nickel nor cobalt. It is difficult, without any details as to its mode of occurrence, to understand the true nature of the enclosing jaspideous rock. It consists entirely, as seen in microscopic section, of very minutely crystalline quartz.

[E. VREDENBURG.]

Vivianite in the Alluvium of Bengal.

Specimens of vivianite associated with logs of wood were found in April last in digging a tank at Jamalpur village (Lat. 22° 39′, Long. 88° 45′) fourteen and-a-half miles in a straight line E. S. E. from Baraset Railway Station in the Baraset Sub-division of the Twenty-four Pergunnahs. The logs of wood are embedded in a stiff clay of pale-blue colour, containing numerous linear impressions of small twigs or stalks. The wood in the larger logs is encrusted with, and apparently partly replaced by, a bright-blue, pulverulent mineral, presenting physical properties and yielding chemical reactions characteristic of vivianite. The depth at which the specimens were found is estimated by the discoverer as thirty feet.

[E. VREDENBURG.]

Recent or sub-recent marine bed in Calcutta.

We are indebted to the courtesy of Mr. G. F. Ross, Manager of the South British Marine Insurance Company, for one of the most interesting

discoveries yet made in the alluvium of Lower Bengal. The excavations for the foundations of some new buildings shortly to be erected in Clive Street, Calcutta, have partly penetrated beyond the made ground and old foundations of former buildings, into the underlying undisturbed sediments. A stratum of large oyster shells met with, at a uniform level, throughout nearly the whole area excavated, attracted the attention of Mr. Ross, who brought the specimens to the office of the Geological Survey. On the 23rd of July Mr. Ross showed me over the ground where the discovery had been made. The trenches, so far opened, were being filled with concrete, but in one of them the section was still visible. The oyster bank at that place was only a few inches thick (probably about half a foot or less), and was situated at about five feet below the level of Clive Street. A thickness of about one foot of the underlying stratum was exposed, consisting of black mud. In all the other trenches, at the time of my visit, the concrete had been built above the level of the oyster-bed, but the heaps of mud and rubbish lying by the side of the excavations were covered with the oyster shells, indicating the presence of the marine stratum over a space of at least one hundred feet square. Mr. Ross and the overseers were unanimous in declaring that the oyster bank occurred at one uniform level whenever met with. In the section visible on the 23rd, one foot, or a little less, of brown mud intervened between the top of the oyster-bed and the bottom of some brick foundations of old walls or buildings. The oyster shells are said to have been found sometimes in layers and sometimes isolated. The first statement is fully borne out by the condition of a great many of the specimens, in which the inferior valve of one oyster is fixed to the dead shell of another. A considerable proportion of the specimens are found with both valves united.

Major A. W. Alcock, F.R.S., Superintendent of the Indian Museum, to whom the specimens were shown, recognised them as identical with a large species of oyster which lives in large numbers in the mud banks near the mouths of the channels of the Sunderbands. Major Alcock mentioned, as a characteristic peculiarity, that the umbonal part of the shell and the ligamental pit often grow to a considerable length, thus enabling the animal to raise its shell above the mud in which it would otherwise be buried. This character is very well shown in some of the Clive Street specimens, in which the ligamental pit sometimes reaches a length of nearly eight inches. It is sometimes straight, or else curiously curved. Judging from their large size and robust appearance, it is improbable that these shells could have flourished much above low-water mark, implying a relative position of the sea and land decidedly different from that obtaining at present. The altitude of the Calcutta oyster-bed is scarcely ever reached even by the highest spring-tides in the Hooghly River. Sufficient data are not available to decide whether this indicates a change of level in the sea or in the land.

species of *Bos*. This suggests that these beds are newer than the ancient alluvial deposits of the Narbada, in which the typical *Bos namadicus* is found. It is noteworthy that Dr. Falconer arrived at the same conclusion with regard to the age of the Jumna alluvium, after examining some fossils obtained thence in 1830,[1] and this conclusion was based on the absence of *Bos namadicus* from these deposits ; the present find shows, however, that it was in existence at this period, though possessing a somewhat advanced type of structure. Assuming on the authority of The Manual of the Geology of India that the Narbada ossiferous deposits are Pleistocene, then these fossils must also be considered of Pleistocene age.

[G. E. PILGRIM.]

[1] Manual of the Geology of India, 2nd Edition, p. 436. Falconer, Pal. Mem. II, p. 640.

G. I. C. P. O.—No. 240. D. G. Survey,—2-9-04.—J. Marum

Photographed by R. D. Oldham. *Bemrose, Colle., Derby, Eng.*

GORGE OF THE ZOJI LA.

Photographed by R. D. Oldham *Benrose, Colls, Derby, Eng.*

VIEW OF THE SIND VALLEY ABOVE BALTAL.

Photographed by R. D. Oldham *Bemrose, Collo, Derby, Eng.*

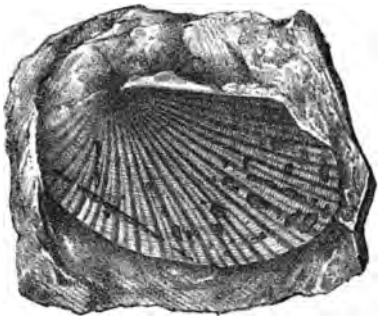
VIEW OF THE SIND VALLEY ABOVE BALTAL.

Photographed by R. D. Olaham. *Bemrose, Collo, Derby, Eng.*

VIEW UP THE SHOKDAR VALLEY.

Photographed by R. D. Oldham. *Bemrose, Collo, Derby, Eng.*

VIEW UP THE SHOKDAR VALLEY.



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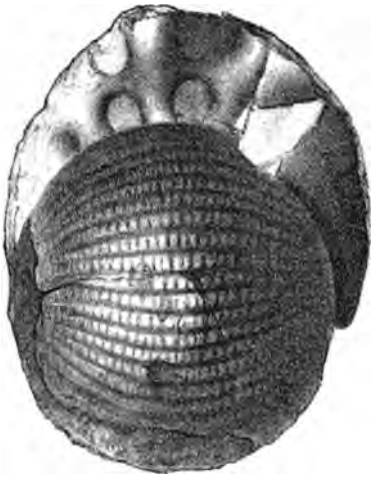

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TRIASSIC FOSSILS FROM BALÚCHISTÁN.

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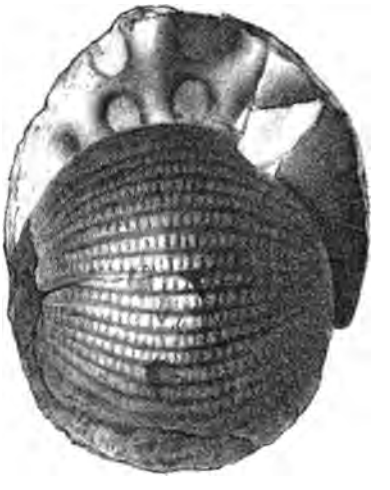

2 *b*

TRIASSIC FOSSILS FROM BALÚCHISTÁN.

Part 2.—The Nahan-Sirmalik unconformity in the North-western Himalaya. On some fossil ossa cordiformia. On the molluscous beds of Hanle in Tibet. Notes on mining records and the mining record office at Upper Burma; and the Coal and Metalliferous Mines Acts of 1872 (Leppard). On cassiterite and stannite from the Khasi mines, Hypersthene with some remarks on saponite (Hayward). On the occurrence of silver at Shillhassetta and Hingalay with barytes in the Kaimur sandstone Measures. Notice of a coal exposure in the island of Cheduba.

Part 3.—Artesian borings in India. On Nilgiri coal granite at Wynaad on the Coffee Northwest Himalayas. On a Sub-pelagic fauna from the Sewaliks. Palæontological notes from the Geological and Zoological Survey Museum. Geological notes from the Siwalik hills in the collections of the British Museum.

Part 4.—Remarks on the utilisation of geological nomenclature and cartography. On the geology of the Aravali region, central and eastern. On a specimen of native antimony obtained at Pelu Chhin, near Gangaw. On Tungsten from the neighbourhood of Jogiyapatti Mamah district, and on silver carbonate from Karaul Madras. Note on the section from Dalhousie to Pangi, via the Sach Pass. On the fourth Darjiling-Himalayan coal-bearing band on Bombay Island.

Vol. XV. 1882.

Part 1.—Annual report for 1881. Geology of Northern Kashmir and Khagan being notes on the geology of Kashmir and neighbouring territories. On some Cretaceous Echinoderms. On some Siwalik and Jurassic fossils. The geology of Dalhousie (North-west Himalaya. On fossils of pelagic Trias from the Gaetano) Marine and Cassian beds in India. On Palæontological Notes on the Sub-Himalayas from Upper Assam and on Palæozoic fossils from Chutia Nagpur. On the occurrence of a copper-yielding lode-system near Yangri hill, in the Darjiling district; (2) Arsenical pyrites in the same neighbourhood; (3) Graphite at Darjiling (being an appendix to a report on the geology and mineral resources of the Darjiling district and the Western Duars). Analyses of coal and fire-clay from the Makum coal field, Upper Assam. Experiments on the use of Pind Panwar Kyan, Burmese, with reference to the production of gas with light yield. Report on the proceedings and result of the International Geological Congress at Bologna.

Part 2.—General sketch of the geology of the Travancore State. The Warkalli beds and reported associated deposits at Quilon, in Travancore. Note on some Siwalik and Narbada fossils. On the Coal-bearing rocks of the valleys of the Upper Tapi and the Moat-ghats in Western Chutia Nagpur. On the Pench-river coal-field in Cohumpoora district, Central Provinces. On borings for coal at Coparia, Rewah District. On sapphires recently discovered in the Northwest Himalaya. Notice of a recent eruption from one of the mud volcanoes in Cheduba.

Part 3.—Note on the coal at Mach (Mach) in the Bolan Pass, and at Khanai or Harnai on the Harnai route between Sibi and Quetta. New facts observed on crystals of sulfate from the Western Ghats, Bombay. On the rocks of Darjiling and Sikkim in the North-western Himalayas. Further note on the connection between the Hazara and the Kashmir series, viâ the Umaira anticlinal (South Punjab Conference paper). The Hydrogeology of Calcutta, Cossipore Hills, Assam. On the outcrops of coal to the Mynpoorie division of the Hazaribagh district.

Part 4.—On a traverse across some gold-fields of Mysore. Journal of borings for coal at Bokhabatta, Cuttack district, in 1879. Note on the supposed occurrence of coal on the Khasi.

Vol. XVI. 1883.

Part 1.—Annual report for 1882. On the genus Richthofenia, Kays (Annette Lawrenciana, Koninck). On the geology of South Travancore. On the geology of Chamba. On the basalts of Bombay.

Part 2.—Synopsis of the fossil vertebrata of India. On the Bijori Intertrappean. On a skull of Hippohyus? antiquus. On the iron ores and subsidiary materials for the manufacture of iron in the north-western part of the Jabalpur district. On Silastic and other manganese ore occurring at Bendipore Jabalpur district. Further notes on the Umaria coal field.

Part 3.—On the microscopic structure of some Dalhousie rocks. On the kaya of Ava. On the probable occurrence of Siwalik strata in China and Japan. On the occurrence of Jurassic vegetation in India. On a traverse between Almora and Manasarowr made in October 1881. On the meteorological circumstances at Darjiling in the Sikkim Himalaya, and Lassa in Tibet.

Part 4.—Palæontological notes from the Daltongunj coal-field in Chota Nagpur. On the altered basalts of the Dalhousie region in the Northwestern Himalayas. On the metamorphic structure of some Sub-Himalayan rocks of tertiary age. On the geology of Jaunsar and the Lower Himalayas. On a traverse through the Eastern Khasia Hills, and North Cachar hills. On native salt from Mauritania and chromite from the Andaman Islands. Notes on a fiery eruption from one of the coral volcanoes of Cheduba island, Arakan. Notes—irrigation from wells in the North-Western Provinces and Oudh.

VOL. XVII, 1884.

Part 1.—Annual report for 1883. Considerations on the comparative antiquities of coal basins of Bengal and Almora on the Travancore coast. Rough notes on Billa Surgum and other caves in the Kurnool district. On the geology of the Chanoti and Bhimtal pergunna of Chamba. On the occurrence of the genus Lytonia Wagner, in the Kaling series of Kashmir.

Part 2.—Notes on the earthquake of 31st December 1881. On the microscopic structure of some Himalayan granites and gneiss-as granites. Report on the Chai coal exploration. On the re-discovery of certain coalities to be found in the Siwalik beds. On some of the mineral resources of the Andaman Islands in the neighbourhood of Port Blair. The inter-trappean beds in the Deccan and the Lameta group in western North America.

Part 3.—On the microscopic structure of some Aravalli rocks. Section along the Indus from the Peshawar Valley to the Sullerange. On the selection of sites for borings in the Raigarh Hingir coal-field (first notice). Notes on lignite near Balaghat, Central Provinces. The Tertiaries of Middle Kathiawar. Notes of a further fiery eruption from the Minbyin mud volcano of Cheduba Island, Arakan. Report on the Langrin coal-field, south-west Khasia Hills. Additional notes on the Umaria coal-field.

Part 4.—On the Geology of part of the Bangenga pergana of British Garhwal. On fragments of slates and schists imbedded in the gneissose granite and granite of the North-West Himalayas. On the geology of the Lakhi Dhaldesman. On the unconformable overlap of the Travancore coast. On ancient sands of the Pulaniah river, Pondicherry district, and phosphatic rocks at Mussuri. Work at the Billa Surgum caves.

VOL. XVIII, 1885.

Part 1.—Annual report for 1884. On the country between the Daltongunj coal-field and the Koelna river. Geological sketch of the country between the Daltongunj coal-field and Hyderabad. On coal and limestone in the Hasdeong river, near Bilaspur, Assam. Translation of Illustrations from Indian Inventions. Afghan field notes.

Part 2.—A fossiliferous series in the Lower Himalaya, Garhwal. On the probable age of the Muschelkalk series in the Lower Himalaya. On a fossil genus of Siwalik cereal (Cerealites pedicus gen. et sp. nov.). On the Geology of Chamba. On the possibility of obtaining water by means of artesian wells in the plains of Upper India. Further considerations upon artesian springs in the plains of Upper India. On the geology of the Abu Hills. On the alleged resiliency of the Arabian mud volcanoes to burst into eruption more frequently during the rains. Analyses of phosphatic nodules and rock from Mussuree.

Part 3.—On the Geology of the Andaman Islands. On a third species of Meryconaterus. Some observations on percolation as affected by current. Notice of the Pirthala and Chandpur meteorites. Report on the chromite and coal in the Thayetmyo district, British Burma. On some cretaceous deposits in the Mooltanee district. On the Kashmir earthquake of 30th May 1885. On the Bengal earthquake of 14th July 1885.

Part 4.—Geological work in the Chhattisgarh division of the Central Provinces. On the Bengal earthquake of July 14th 1885. On the Baluchistan earthquake of 28th May 1885. On the results of Mr H. B. Foote's further excavations in the Billa Surgum caves. On the mineral Siberite known as Neptunite. Notice of the Salsettewadi meteorite.

VOL. XIX, 1886.

Part 1.—Annual report for 1885. On the International Geological Congress of Berlin. On some Palæozoic fossils recently collected by Dr H. Warth, in the Olive group of the Salt range. On the correlation of the Indian and Australian coal-bearing beds. Afghan and Persian field notes. On the section from Ilorin to Wangtu and on the petrographical character of the Amphibolites and Quartz Norites of the Satlej valley.

Part 2.—On the Geology of parts of Bashey and Amritgarh districts. Geology of the Upper Deling basin in the Sangpo. 1870. On thermo-metamorphic structure of some eruptive rocks from the Central Himalayas. Preliminary note on the Mammalia of the Narbada Caves. Memorandum on the prospects of Indian coal in Western Rajpootana. Note on the Illite group of the Saltranges. On the dissolution organisms the nummulitoids of the Saltranges. On the Goodenough Hummocks.

Part 3.—Geological sketch of the Visagapatam district, Madras. Preliminary note on the geology of Northern Jeypore. On the microscopic structure of some specimens of the Malani rocks of the Aravali region. On the Metamorphoses sandstone in the Balaghat district, C. P.

Part 4.—On the occurrence of petroleum in India. On the petroleum exploration at Khushab boring exploration in the Chhattisgarh coalfields. Field notes from Afghanistan. No. 1. Turkistan. Outline of a new eruptive from one of the east volcanoes of Central Asia. Arsikan. Outline of the Nimmalurkhal sandstone. Analysis of gold dust from the Mosa valley, Upper Burma.

Vol. XX. 1885

Part 1.—Annual report for 1884. Fieldnotes from Afghanistan; No. 1, from Turkistan to India. Physical geology of West Gurhwal; with notes on a recent trip to Borendo Jumnotri and Gangotri. On the geology of the Khasi Hills. On some Indian sandstones. On sandstone recently found on Barren Island and Mayorabunder. On a character of the Talchir boulder-beds. Analysis of Phosphatic nodules from the Salt-ranges, Punjab.

Part 2.—The fossil vertebrata of India. On the Hydrology of the calcareous region of the Lower Narbada Valley, with remarks upon their geological age. Fieldnotes; No. 2.—to accompany a geological sketch map of Afghanistan and North-eastern Khorassan. On the microscopic structure of some specimens of the Rajmahal and Diamon trees. On the mineralogical character of the Talchir boulder-beds. Analysis of Phosphatic nodules from the Salt-ranges, Punjab.

Part 3.—The retirement of Mr. Medlicott. Notes of T. D. Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of the Lower Himalaya, Darjeeling, and Sikkim. Section I. Preliminary sketch of the geology of Sikkim and Independ. Notes on the "Lalitpur" meteorite.

Part 4.—Note on some points in Himalayan geology. Crystalline and metamorphic rocks of the Lower Himalaya, Darjeeling and Sikkim. Section II. The iron industry of the western portion of the District of Salem. Notes on Upper Burma. Boring explorations in the Chhattisgarh coalfields. Colonial project. Notes relative to Professor Heim's morphism, with reference to the folding of the Himalayan Cretaceous Groups. A list and index of papers on Himalayan Geology and Himalayan Petrology published in the preceding volumes of the records of the Geological Survey of India.

Vol. XXI. 1886

Part 1.—Annual report for 1885. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaon. Section III. The Bijawar series of Bijawar (Central India). Memorandum on the results of an exploration of Jessalmer, with a view to the discovery of coal. A faunal publication from the Saraide Sal ('petrified sandstone') of Mount Chail in the Salt-ranges in the Punjab. Examination of sedimentary stones obtained by trawling off Colombo.

Part 2.—Award of the Wollaston Gold Medal, Geological Society of London, 1885. The Dharwar System, the chief sedimentary series in South India. On the igneous rocks of the districts of Raipur and Balaghat (Central Provinces). On the Sanger Marg and Meloneguda coalfields (Kistna).

Part 3.—The Manganese Iron and Manganese Ores of Jabalpur. The Carboniferous Glacial Period. The sequence and correlation of the principal sedimentary formations of the Sub-Himalayan region of the Lower Himalayas.

Part 4.—On Indian fossil vertebrates. On the geology of the Mandarwa Himalayas. On blown-sand rock sculpture. Re-discovery of Nummulites in Zanskar. On some more maps from Zanskar and Ladakh.

Vol. XXII. 1885.

Part 1.—Annual report for 1885. The Dharwar System, the chief auriferous rock-system in South India. (Second notice.) On the Wajra Karur diamonds, and on M. Chaper's alleged discovery of diamonds in serpentine near that place. On the generic position of the so-called Pleurotomaria Indicæ. On fossil sandstone in Travancore, with special reference to its burrow and tracks of crustacea in India, and the cause of its peculiarly thin bedding and laminæ. On Cassidy and Gabriola Chalcopite.

Part 2.—Note on Indian Fossilæ. Diamond pebbles in the Sawath conglomerate. The 'Carboniferous Glacial Period.' Notes on Dr. H. Woodward's 'Carboniferous Glacial Period.' On the silicified wood of Twingoung and Nemo, Burma. The gypsum of the Natal Coal Measures. On many of the materials for pottery obtainable in the neighbourhood of Jubbulpur and of Umaria.

Part 3.—Abstract report on the coal outcrops in the Sharigh Valley, Baluchistan. On the discovery of Eocene by Dr. H. Woods in the Waziristan hills of the Sulaiman range. Geological notes. On the Cherra Poongru coal-field, in the Khasia Hills. On a Lower Silurian Reef from Hegali. The President of the Geological Society of London on the International Geological Congress of 1888. Tin-mining in Mergui district.

Part 4.—On the Lead-ores of the Aravallis. On the galena of Lunawarra from the Aravallis. Recent assays from the Rajpootana Gold-fields in Rajpootana. The Manganiferous Iron and Manganese Ores of Jubulpur. On some Palæozoic fossiliferous rocks of the Rajmehal hills and Deccan. On tin-smelting in the Malay Peninsula. Provisional index of the local distribution of important economic mineral products, gemstones, and quarry stones in the Indian Empire. Part 1.

Vol. XXIII. 1886.

Part 1.—Annual report for 1885. On the Lilladong coal-fields (south) Hills. On the Perasol and fossil girdles and shell of the Indian Dicynodonts. On certain vertebrate remains from the Sirmur district (with description of a Rat-shrew). Crystalline and metamorphic rocks of the Lesser Himalayas (Garhwal and Kumaun). Section IV. On the structure of the Hive-group Sub-group. On the coal-basins of the Transvaal coast.

Part 2.—On the most favourable areas for Petroleum explorations in the Himalayas (etc.). Baluchistan. The Sapphire Mines of Kashmir. The supposed Mines of the Diamond in Wairi Land, Mysore. The Sangur Gold-field. Fossil Plants from the Shan Hills (Upper Burma). A description of some new species of Stylocoenidæ, with remarks upon their structures, &c.

Part 3.—On the Geology and Economic Resources of the Country adjoining the Sind-Pishin Railway between Sharigh and Bostanzai and of the country between it and Khattan (with a map). Report of a journey through Salt in the winter of 1885-86, by G. Johannes Wilson, translated from the German, by H. Bruce Foote. On the Continuity of Lateralite, Warkalite, and Sub-lateralite, in the Rajmahal Hills (with a plate). Further Notes on Indian Silicifie. Provisional Index of the Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones, and Quarry Stones in the Indian Empire (continued from p. 286, Vol. XXII).

Part 4.—Geological sketch of Nandi Hill with some remarks on the natural conditions governing mountain slopes (with a map and plate). Notes on some Fossil Indian Red Woods. The Distilling Coal between the Lias and the Raniganj rocks, explored during season 1885-86 (with a map). The Basic Eruptive Rocks of the Kadapah Area. The Limp Stones at Lanowar. Preliminary Note on the Coal Seams of the Deccan Trap Series (with two plates).

Vol. XXIV. 1890.

Part 1.—Annual report for 1889. On the Geology of the Salt range of the Punjab, with a reconsidered theory of the Origin and Age of the Salt Marl (with five plates). On veins of Graphite in Crystalline Gneiss Laterite, in Ceylon. Extracts from the Journal of a Trip to the Glaciers of the Indus, Section I. (The Salts of the Sambhar Lake in Rajputana, and of the Saline efflorescence called 'Reh,' from Aligarh in the North-Western Provinces. Analyses of Dolomite from the Salt range, Punjab.

Part 2.—Preliminary Report on the Oil locality near Maghal Kot in the Bannu country, Sulaiman Hills. On Minerals Oil from the Sulaiman Hills. Note on the Geology of

the Lushai Hills. Report on the Coalfields in the Northern Shan States. Notes on the reported Naphtha Refineries in the Minglôn State. Note on the Townsendite (Columbite) Mines in the Minglôn State. Note on a Saltspring near Nawgyi, Thônze State.

Part 2.—Mining Exploration in the Darjeeling Coalfield. Pyroxene (with a map). Death of Dr. P. Martin Duncan. Contributions to the study of the Pyroxenic varieties of Granite and of the Leopoldsburg Rocks.

Part 3.—On a Collection of Mammalian Bones from Mongolia. Further notes on the Darjiling Coal Exploration. Notes on the Geology and Mineral Resources of Sikkim (with a map). Chemical and Physical notes on rocks from the Salt range, Punjab (with two plates).

Vol. XXV, 1895.

Part 1.—Annual report for 1895. Report on the Geology of Thal Chotiali and part of the Mari country (with a map and 5 plates). Petrological Notes on the Ratanbenat of the Salt range, Punjab, Jalkeryans and Cannel Deposits of the valley basins of Quetta, Pishin, and the Dasht-i-Bidaulat, with appendices on the Chamans of Quetta, and the Affghan water-supply of Quetta.—(4 Plates (with one plate).

Part 2.—Geology of the Salt Hills (with 2 plates of sections). Report on a Survey of the Jhanzi Coalfield (with a map and 3 section plates) (out of print).

Part 3.—Note on the Locality of Indian Tadpole-Shells. Geological Sketch of the country north of Bhamo. Preliminary Report on the economic resources of the Amherst and Sebungmines area in Upper Burma. Preliminary Report on the Limestone and Iron Industries of the Salem District. On the Occurrence of Bituminite in India. Coal on the Great Tenasserim River, Mergui District, Lower Burma.

Part 4.—Report on the Oil-Springs of Minbyé Kun on the Minbyé Hills (with 2 plates). Second Note on Mineral Oil from the Sulaiman Hills. On a New Fossil Snake-like Fish occurring in Burma. Preliminary notice on the Triassic Deposits of the Salt range.

Vol. XXVI, 1895.

Part 1.—Annual report for 1895. Notes on the Central Himalayas (with map and plates). Note on the occurrence of Jadeite in Upper Burma (with a map). On the occurrence of Bauxite in the Fossil Resin from Upper Burma. Report on the Prospecting Operations, Mergui District, 1893-95.

Part 2.—Notes on the earthquake in Baluchistan on the 20th December 1892 (with 2 plates). Further Note on Tantalite, a new source for Tin-stone from Upper Burma. Note on the Alluvial deposits and Subterranean water-supply of Rangoon (with a map).

Part 3.—On the Geology of the Shirani Hills (with map and plates). On Carboniferous Fossils from Tenasserim (with 3 plates). On a deep Boring at Chanda (Nagpur). Note on Bauxite in the districts of Tavoy and Mergui (with a plate).

Part 4.—On the Geology of the country between the Chappar Rift and Harnai in Baluchistan (with map and 2 plates). Notes on the Geology of a part of the Tenasserim Valley with special reference to the Tenasserim Kaolin-bearing Coal-field (with two maps). On a Magnetic Survey from the Madras Presidency comprising Mauritius and Alumina. On Hullsite (Hauyne-ite) (with a plate).

Vol. XXVII, 1896.

Part 1.—Annual report for 1895. Report on the Bhagavasta Coal-field (Salt range, Punjab) (with map and 9 plates).

Part 2.—Note on the Chemical qualities of petroleum from Burma. Note on the Bhagavasta Coal-field, Hydrostal (Diorite) (with map and 3 plates of sections). Report on the Golden Laudaite, Gadwal (with 3 plates and a map).

Part 3.—On the Cambrian Formation of the Eastern Salt-range (with 2 plates). The Giridih (Karharbari) Coal-field, with notes on the fauna and methods of working (with 2 maps and 2 plates of sections). On the Occurrence of Chlorite in Plants in the Upper Miocene of Burma (with a plate). Note on the Occurrence of Velates Schmideliana, Chemn., and Provenasa praedia, Sow., in the Tertiary Formation of India and Burma (with 2 plates).

Part 4.—Note on the Geology of Wuntho in Upper Burma (with a map). Preliminary notice on the Rekhalds from the Upper Cretaceous System of Baluchistan. On Highly Phosphatic Mica-Peridotites intrusive in the Lower Gondwana Rocks of Bengal. On a Mica-Hypersthene-Harzburgite-Peridotite in Bengal.

VOL. XXVIII, 1895.

Part 1.—Annual report for 1894. *Cretaceous Formation of Pondicherry.* Some early allusions to Barren Island; with a few remarks thereon. Bibliography of Barren Island and New Guinea, from 1884 to 1894; with some remarks.

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THE GEOLOGY OF UPPER ASSAM, *by* J. MALCOLM MACLAREN, B.Sc., F.G.S., *Mining Specialist, Geological Survey of India.*

Introduction.

The country considered in this report is that lying north of the 27th parallel of north latitude, and bounded in all other directions by the mountain ranges which wrap round the head of the Assam Valley—the Himalayas on the north-west, the Miju Ranges on the east, and the Patkai on the south-east. Except for the low spurs of the Tipam Hills, north of Jaipur, and the Manabum ridge, near the Brahmakhund, there is nothing in this area to break the level monotony of a plain that stretches down the valley with a breadth of some 60 miles, and that, though more than 500 miles from the sea, has an average elevation of about 430 feet, and a range, within the area shown on the attached map, of only from 320 to 500 feet above sea level.

The salient feature of the country is, of course, the Brahmaputra River with its great tributaries:—the Subansiri, the Dihong (the Tibetan Tsanpo), the Dibong, the Lohit or the sacred affluent of the Brahmaputra, and the Dihing. With the exception of the Subansiri and the southern branch of the Dihing, these streams converge at a point near Sadiya to form the main river. As might be expected in a region with an average annual rainfall of 115 inches, and that nearly all precipitated during seven months in the year, the country is everywhere intersected by minor waterways, the winding channels of which are in striking contrast to the direct course pursued by the main river in this portion of the valley.

Of the physical features of the hills bounding the plain it is impossible to say much. These ranges are, without exception, inhabited by wild hill tribes, whose open or covert hostility, superadded to the difficulty of obtaining transport and the natural inhospitality of the mountains, makes a journey into them a matter of great difficulty if not of actual danger. Indeed, our limited knowledge of the geology of their interior has been mainly obtained during the progress of punitive expeditions conducted against tribes far apart—the Aka Tanangs and Daphlas in the extreme west, and the Singphos in the east.

Our knowledge of even the foothills, with the exception of those lying near the Makúm and Jaipur coal-fields, is very scanty, and is derived from isolated observations at widely separated points.

It will therefore be apparent that the following sketch of the geology of the area can make no pretensions whatever to completeness, and its *raison d'être* lies merely in the fact that it will be many years before a complete geological view of these hills is obtained—probably many before our knowledge of them is materially increased. Deductions have therefore in some cases been made from the occurrence of rolled and water-worn fragments in stream beds, ordinarily a most reprehensible practice and one only adopted in this paper where direct observation has been impossible; but wherever such has been the case, the fact has been explicitly stated, and no misconception can arise under that head.

Geology.

The following table shows the formations dealt with in the course of this paper:—

Archæan } Purana }	Granite, gneiss, schists, slates, and limestones. The Daling Series—quartzites and slates.
Permo-Carboniferous	Lower Productus limestones (rolled fragments).
Permo-Trias	Damuda Series—shales, coal seams, etc.
?	Disang Series—sandstones and shales.
Middle Tertiary	Coal Measures of Makúm, Jaipur, etc.
Upper Tertiary	Tipam and Sub-Himalayan sandstones.
Pleistocene	High level gravels.
Recent	River alluvium.

Metamorphic and crystalline rocks.

Rocks falling under this head are restricted to the mountain ranges, and, with one exception, to the interior and to the higher of these. They appear nowhere in the Patkai Range, which is wholly, or almost wholly, composed of tertiaries, but are largely developed in the mountains to the east, north, and north-west of the valley. Previous to the work of the present season they had been recorded *in situ* in the Daphla Hills by Colonel Godwin-Austen,[1] and doubtfully *in situ* by Mr. La Touche in the Upper Dihing Valley in the Singpho Hills,[2] and further by the latter observer in the Aka Hills at a point some 40 miles west of Godwin-Austen's traverse. La Touche's observations in the Singpho Hills indicate the presence at the head of the Dihing Valley of a strongly foliated garnetiferous hornblende schist. Judging also from the débris of the Kamlang Pani, a stream flowing into the Brahmaputra above Chonkam, it is probable that the higher points of the Dapha Bum Range, culminating in Mathaidong (Dapha Bum), 15,010 feet, are of gneiss and granite, and that an axial core of these rocks extends a considerable distance to the north-west along the strike of the flanking metamorphics.[3]

No distinctive name has as yet been assigned by geographers to the great ranges that lie transversely across the head of the Assam Valley from Dapha Bum northwards, though that to the far east between the head waters of the Irawadi and of the Brahmaputra has

[1] Jour. As. Soc. Beng., Vol. XLIV, Pt. II, p. 35.

[2] Records, Geol. Surv. India, Vol. XIX, Pt. II, 1886, p. 113.

[3] Since writing the foregoing I have met with several geological notes in the journals of Lieutenants Wilcox and Rowlatt, bearing directly on the geology of the Miju Ranges. To Wilcox, though his journeys were made as long ago as 1828-1832, we are still indebted for all our knowledge of the older rocks of these mountains. He found that, as far as he was able to penetrate (25 miles E.-N.-E. of the Khund), the rocks were metamorphic, intruded in places by syenitic and by ordinary granite (As. Res., Vol. XVII, pp. 370-386). The latter was *in situ* at the So stream. The hornblende schists and epidiorites apparently have a considerable development in the interior, for Wilcox's last geological note before commencing his return journey reads: "All the rock on our course was hornblende and greenstone."

On his expedition to the Bor-Kamti country he noted "gneiss and mica slate" on the crest of the range between the Dihing and the Dapha Pani, "syenite" beyond the Phungan Bum, and "mica slate" between the Namlang and the Irawadi (*loc. cit.* p. 448). His "mica slate" we would probably now term a schist.

been termed, by Prince Henri d'Orleans, the Zayul Range. In subsequent portions of this paper these mountains will, for purposes of brevity and precision, be termed the Miju Ranges, from the name of the powerful Mishmi tribe inhabiting the inner valleys.

At the Brahmakhund the metamorphic rocks occur *in situ*. They are here quartz schists, striking N.-W. and S.-E., and dipping N.-E. at angles of 45°. The sacred pool of the Hindus is situated at the bend of the river, where the stream, after flowing from the north-east across the strike, suddenly turns to the north-west and continues its course parallel with the strike. The pool itself is formed in a back eddy of the main basin, where the river has cut a channel across a narrow hard band of rock and has eroded a softer stratum behind, thus forming a recess 40 feet wide and extending behind the tongue of hard rock for a distance of some 70 feet.

Some 6-7 miles north-west of the Khund, the same schists are exposed along the base of the hills in the bed of the Tymi stream, together with a garnet and an amphibolite-schist, the ferro-magnesian constituent of the latter occasionally occurring to the almost complete exclusion of the quartz. Still further north-west, in the Dora Pani, the last exposure of these rocks was found. Here, four or five miles from Dora Mukh, is located the famous hill of "Rukhmini pitha,"[1] about 150 feet in height, and composed of more or less pure kaolinite. The rock in the only section seen was thoroughly decomposed, and its original condition can only be guessed at. It was probably a schist composed of quartz, of a felspathoid constituent, and of a ferro-magnesian silicate, the last by decomposition furnishing chlorite. In places the original strings of quartz are prominent, but the great mass of the quartz is now scattered in small grains throughout the kaolin. The dip of these rocks is naturally not very clear, but seemed to be easterly to north-east at a medium angle.

At the Brahmakhund the rock débris in the river bed is composed of granite and hornblendic gneiss, of quartzite, forming a very large percentage of the whole, and of limestone and serpentinous boulders. The quartzite not improbably represents a portion of the Purana

[1] According to the Jogini Tantra, this hill is the remains of the marriage feast of Raja Sisopal and of Rukhmini, the daughter of a neighbouring king named Bhismak. Rukhmini, being abducted by Krishna before the conclusion of the ceremony, the whole of the viands were left uneaten and have since been consolidated into their present form.

series (the former Transition or Dharwarian of the Peninsular area), resembling in its lithological features the Shillong quartzites of the Khasi Hills to the south-west.[1] Of the source of the crystalline limestone pebbles found in the Brahmaputra, considerable information is afforded by their distribution in the various streams. Neither in the Tymi nor in the Dora are they found. In the former the débris is exclusively schistose, in the latter schistose and quartzitic. These are both streams flowing from the outer range, which rises here to an altitude of some two to three thousand feet. Turning now to those streams which have a longer course and have cut a way through the first range, we find that limestone is brought down by the Brahmaputra and by the Digaru. While the percentage carried by the former is inconsiderable, there are places in the Digaru where limestone pebbles exist to the almost complete exclusion of all others, indicating that the watershed of the latter stream is almost entirely in the limestone. The final indication of the position of the limestone belt is furnished by the complete absence of its pebbles in all the streams to the west of the Digaru. The Dibong, some of whose eastern tributaries might have been expected to reach it in that direction, from its stream bed shows no evidence of having done so, though the presence of schistose rocks indicates that the streams have reached the schists which are known to lie to the west of the limestone. It is true that one boulder of limestone was found above Bomjor in the Dibong, but it is considered almost certain that this was derived from the recent high level gravels of the Brahmaputra which, as will hereafter be shown, lie in patches along the whole length of the northern foothills. From the foregoing evidence it seems reasonable to infer that the strike of the limestone is N. W.—S. E., parallel with the schists.[2] The dip also of the strata further east is probably parallel with that of the schists at the Brahmakhund, since, as far as could

[1] Memoirs, Geol. Surv. India, Vol. VII, p. 197.

[2] The following valuable geological notes are contained in the journals of Lieutenants Wilcox and Rowlatt (As. Res., Vol. XVII (1832), p. 370, and J. A. S. B., Vol. XIV (1845), p. 482, respectively), and bear directly on the subject, furnishing indeed the exact locus of the limestone. The former says:—"The base of Thematheya" (perhaps 8 miles from the Brahmakhund) "on our right, is of the same grey carbonate of lime,...and perhaps the whole mountain." Lieutenant Rowlatt adds:—"On leaving the bed of the Tiding" (10 miles N.-N.-E. of the Brahmakhund) "the road continues over the spurs of the mountains, and for some distance passes under the perpendicular cliffs of primitive limestone, from which are visible the pendulous stalactites that are peculiar to this formation."

be judged from the moderate height reached in the hill above the Khund, the ranges to the east appear to present a much steeper slope to the north-west than in the opposite direction. There can be little doubt that these rocks are the direct continuation of the Burmese axials, for the latter to the south have precisely the same angle of dip, and their strike[1] to the north-west will carry them exactly to the point where they have been found on the Brahmaputra. Further, a continuation of this strike beyond the Khund will restrict them exactly to those limits which were above assumed from a consideration of their detritus. From geological, as well as from orographical conditions, it then follows that the true termination of the great Himalayan chain must be considered to lie along a north-west line from the Brahmakhund. Orographically, the separation from the Miju Ranges may be deduced from the fact that, while the waters of the Digaru and of the Dibong find their easiest courses to lie in a general E.—W. direction, the valley of the Brahmaputra, the only river which really breaks into the Miju Ranges, gradually turns to the north, until its headwaters flow south, parallel with the great Burmese river system, which is continued in the Salween and Mekong, far into Tibet, and to which system the short meridional portion of the valley of the Lohit Brahmaputra or Zayul may indeed at one time have belonged.

Of the granite and gneiss of these mountains, nothing definite can be said. They probably, from their resistance to denudation, form the higher ranges of 11,000 to 14,000 feet. The Miju Ranges give considerable promise of containing deposits of economic value. The schists, where seen, contained merely lenticles and stringers of quartz and no true quartz veins, but they are nevertheless the probable source of all the gold that is now so widely scattered over the Upper Assam Valley. Whilst among the Kamtis, the writer was shown several specimens of pyrite, of chalcopyrite and of galena, all from the Bor Kamti country to the east. From the two latter minerals the Bor Kamtis extract copper, and lead and silver respectively, and no *daos* are so highly prized among the natives at the head of the Assam Valley as those made from Bor Kamti iron. The locus of the argentiferous galena is certainly the crystalline limestone, and of the chalcopyrite either the less altered schists or, much more probably, the serpentinous rocks.

At the present time the only economic use made, in territory

[1] Records, Geol. Surv. India, Vol. XXVI, Pt. I, p. 28.

directly under British administration, of these older rocks is of the limestone, which in the form of boulders is collected during the cold weather from the Digaru and from the Brahmaputra, and carried to Saikhwa Ghat and to Dibrugarh to be distributed and burned for lime for agricultural and constructive purposes. None other than this so called "Sadiya lime" is used in the Dibrugarh district. It varies in colour from bluish-black to white, and is, from its completely crystalline nature, quite unfossiliferous. It seems to have been originally so pure that metamorphism has developed in it no accessory minerals, in this respect differing somewhat from the Burmese limestones, which generally contain actinolite.

On following the Himalayas along the valley to the west, little evidence of value concerning the nature of the mountain ranges was afforded by either the Dibong or the Dihong. The only difference between these rivers lies in the absence in the Dihong of the schistose débris already mentioned as occurring in the Dibong. Otherwise the deposits of both are characterised by great quantities of quartzite, white or pink, and of an amygdaloidal diabase, these two rocks, together with a fine jasperoid conglomerate, constituting quite 95 per cent. of the whole débris in the latter river. Little attention was given to the Dihong, partly from lack of opportunity, but mainly from the fact that it drains such a vast area on the northern side of the Himalayas that no deductions whatever can be made from the occurrence of a particular rock in its bed. The scarcity of granite and gneiss is, however, interesting.

Still further west, the Subansiri River affords some information concerning the nature of the hills. Here, as in the Dihong, granite is rare, and such as does occur is derived from the high level river gravel already mentioned. Gneiss of a strongly foliated type is fairly abundant, but, as before, the main mass of the detritus is composed of quartzite, both white and pink. This predominance of quartzite by no means certainly represents an equally wide distribution in the hills, but is merely due to a naturally high resistance to weathering agents. Small quantities of a slate, so schistose as to deserve the name of phyllite, represent in all probability the Daling Series of Purana rocks first described by Mallet in Sikkim[1] and by La Touche and Godwin-Austen in the papers already quoted. La Touche describes them *in situ*, some 80 miles west of the Subansiri, as nearly

[1] Memoirs, Geol. Surv. India, Vol. XI, Pt. I.

vertical micaceous slaty schists, occasionally fine-grained and fissile, striking east and west.

Godwin-Austen found them to be represented on the Dikrang River by white quartzites and micaceous schists dipping 55° S. E., with a very regular N. E.—S. W. strike.

Permo-Carboniferous.

Among the boulders heaped at the mouth of the Subansiri gorge a few fossiliferous fragments were detected. A most careful search resulted in the collection of some twenty similar boulders and pebbles. These may be divided according to lithological characters as coming from two minor horizons, the boulders of one being composed of an extremely hard black marly limestone, often with the fossils more or less centrally disposed, pointing not so much to concretionary structure as to a radial hardening round the shell by outward transference of its carbonate of lime, while the second division has its fossils embedded in a much more arenaceous rock, sometimes indeed so coarse in texture that it is a matter for surprise that the fossil form should have been preserved. The principal fossils are the following :—

(*a*) In the arenaceous rock—

Productus sp.
Dielasma cf. La Touchei, Dien.
Dielasma sp.
Spirifer cf. convolutus, Phill.
Spirifer sp.
Platyschisma ? sp.

(*b*) In the marly limestone—

Productus sp.
Chonetes sp.
Nuculana subacuta, Waag.
Myalina sp.
Pleurotomaria (Mourlonia) cf. Strzeleckiana, Morris.
Bellerophon sp.
Orthoceras sp.
Fenestella sp.

These, it will be seen, have a facies distinctly Permo-Carboniferous, and are perhaps to be correlated with the Lower Productus Limestone of the Salt Range. Beds of this age have been known hitherto only

from the Salt Range and more recently from Spiti,[1] and the present occurrence appears to connect these with the Chinese occurrences,[2] and possibly with the Permo-Carboniferous strata of Tenasserim [3] and of the Southern Shan States.[4]

Of the locus of the fossiliferous bed, it is impossible to say more than that it is in the basin of the Subansiri river system. It may possibly be looked for at the base of the Damuda Series at no very great distance from the Assam plain, along the probable continuation indicated by the two isolated occurrences of those rocks shown on the accompanying map; but, from our recently acquired knowledge of the extension of the younger Spiti shales along the northern flank of the gneisses and metamorphics of the Himalayas, it seems also possible that these fossils have been brought from the headwaters of the Subansiri, which, as far as our knowledge of its course goes, appears to cut through the main chain and have its sources on the edge of the Tibetan plateau. The general appearance of the boulders gives no clue to the distance they have travelled.

Permo-Trias—Damuda Series.

Rocks belonging to this period were described by Mallet,[5] in Sikkim, considerably to the west of the Assam area. There they had suffered greatly from orogenic movements, and their contained coal seams were thoroughly crushed.

On the upper waters of the Bhoroli River, which joins the Brahmaputra at Tezpur, La Touche found Damuda rocks occurring as narrow contorted bands of hard grey quartzitic sandstones interstratified with carbonaceous shales and seams of coal, the whole dipping at very high angles and generally to the south.[6]

Godwin-Austen[7] met with them on the Dikrang River further to the east, where they had a well-defined N. E.—S. W. strike and dipped indifferently at high angles (70°-75°). They were there clay shales, often carbonaceous, interstratified with dark close-grained sandstones. The carbonaceous shales occasionally pass into a crushed splintery coal.

[1] Hayden, Mem. Geol. Surv. India, Vol. XXXVI, Pt. I.
[2] Pal. Indica, Series XIII, Vol. IV, p. 168, (1891).
[3] Manual Geol. India, p. 142.
[4] Genl. Rept., Geol. Surv. India, 1899-1900, p. 139.
[5] Memoirs, Geol. Surv. India, Vol. XI., Pt. I, p. 14.
[6] Records, Geol. Surv. India, Vol. XVIII, p. 122.
[7] Jour. As. Soc. Beng., Vol. XLIV, p. 37.

Disang Series.

This is a series of sandstones and shales distinguished by Mallet[1] and occurring to the south-east and south of Jaipur. They are of considerable thickness, and dip to the east and south-east at fairly high angles. The sandstones are "grey to greenish-grey, fine-grained and rather hard, they are mostly thin-bedded, with occasional layers of grey shale, but in some parts thick and thin beds are intermixed." The shales are splintery and grey and at times contorted, and are occasionally clunchy. The whole series is unfossiliferous, and it is extremely difficult to ascribe an age to the group. They are almost certainly older than the coal measures, which they appear to underlie and with which they are in contact only along a faulted boundary. From their lithological resemblance to certain beds of Manipur, of the Arakan Yoma, and of Burma, they have been tentatively grouped by Mallet with the Arakan-Negrais. To this classification there are several objections. The Disang beds contain neither serpentinous intrusions nor indurated cherts, nor are they as highly contorted as are the rocks of the Negrais group. Moreover, quartz veins, though occurring in the Disang rocks, are not so characteristic of them as of the Negrais. On the whole, therefore, it seems probable that these beds are to be correlated with the Tertiaries, and confirmation of this assumption is afforded by a study of the geology of the Mikir Hills in the south-west, where rocks, very similar lithologically to the Disang Series, are known to overlie the Eocene nummulitics.[2]

Serpentinous boulders are far from uncommon in the Upper Dihing, and La Touche (*loc. cit. sup.*) has recorded the presence, at about a mile below the pass from the Dihing to the Irawadi, of fine-grained fissile slates. He expresses no opinion regarding the age of these, but it is probable that they represent more truly the Arakan-Negrais and the Manipur Series than do those of the Disang Series.

Coal Measures.

These are best known in the Makúm district, where the contained coal seams are being extensively worked, but they stretch for forty miles north-east and for a hundred miles south-west, being exposed only along the northern front of the Patkai Range. They consist of

[1] Memoirs, Geol. Surv. India, Vol. XII, Pt. II, p. 18.
[2] Memoirs, Geol. Surv. India, Vol. XXVIII, Pt. I, p. 91.

alternating shales, sandstones, and coal, with a few thin calcareous layers. The sandstones are generally thin-bedded, containing, more especially to the south of Margherita, nodules of clay ironstone. The shales are grey, and weather, where the conditions are favourable, to a tough, tenacious, blue clay. Near the coal seams they pass into carbonaceous shales, often showing fairly distinct impressions of dicotyledonous leaves, which give, however, no real clue to the age of the measures. At Margherita the coal appears to attain its maximum thickness, the "thick" seam now being worked averaging some 50 feet, and reaching in the Namdang section as much as 80 feet.[1] The seam is very persistent in length, the Margherita workings showing little variation in a distance of six miles. The most remote coal seams that have been noted [2] in this area are on the flanks of Maiobum in the Dihing Valley.[3] Further south-west they occur in the Namrup, and in the Namchik. Between the Tirap and the Namchik there appears to be a gap, due no doubt to the embaying of the range and the consequent denudation to the plain level of the coal measures. From the Tirap to the Namsang River, a distance of 20 miles, the measures appear to be continuous, but the great reversed fault which runs along the base of the hills, and which indeed marks their northern limit, has at the latter place either raised the seam sufficiently high to enable the Namsang stream to completely erode it down to the presumably underlying Disang series, or it lies hidden beneath the gravels of that stream. A second reversed fault to the north-west has raised and exposed the same coal measures along the north-western flank of the Tipam Hills, from whence they strike east of Jaipur to a little beyond the Disang River. Similar coal measures are brought to the surface by the same or similar faults in the hills south of Nazira and of Moriani respectively.[4]

Not the least interesting feature of these coal measures is the almost invariable association with them of petroleum oil springs, an association so marked as to force the conclusion of a genetic connection between the oil and the coal.

During the work of the present season the area of the coal

[1] G. E. Harris, Trans. Manchester Geol. Soc., Pt. XIX, Vol. XXVI, p. 572.

[2] La Touche, *loc. cit.*

[3] Wilcox (As. Res. Vol. XVII (1832), p. 420) saw, on the right bank of the Dihing above the mouth of the Dapha Pani, "thin strata of coal alternating with blue clay in the sandstone rock."

[4] Mallet, Memoirs Geol. Surv. India, Vol. XII, Pt. II.

measures has been extended by their discovery in the Manabum Range, a long spur parallel with the Noa Dihing and running out from the Miju Mishmi country into the plains as far as the Tenga Pani. This spur is best seen from the slopes of the hills above the Brahmakhund, when it appears as a long low range of even height lying along the western horizon. Owing to the fact that the work of the season was primarily devoted to the economic investigation of the auriferous deposits, little time was available for purely geological work. The range was therefore examined in one place only, at a spot about 200 yards above Tenga Mukh. The rocks obtained left no doubt of the correlation to be adopted. They were sandstones of the true Tipam type occurring with grey shales containing ill-defined leaf impressions. The brief half hour which it was possible to give to the examination of the section, covered as it is with dense jungle, gave no clue to the relations of these two members, but it seemed likely that the sandstones of the Tipam type were not in force, and that the section represents a horizon somewhat high up in the coal measures. On ascending the hill above the section great quantities of loose quartz pebbles were exposed. These may represent a conglomerate bed in the series, but are to be referred with much more probability to an old river terrace.

So far as is known, coal measures are absent from the hills to the north of the Brahmaputra. Beyond Nizamghat, at the gorge of the Dibong River, a spot was pointed out by my Chulikotta Mishmi guide who affirmed that by day a cloud of black smoke and by night flames arose from the ground at that place. From his extremely circumstantial account, and from his care in indicating the exact spot on the slope of the opposite range, it seems at least probable that he was referring to a burning coal seam, such as has altered to coke much of the outcrop coal at Margherita. Fragments of coal have been picked up in the Dibong, but no importance need be attached to the fact since the overlying sandstones, which have here a considerable development, furnish numerous stringers and nests of lignite, the finding of which has often given rise to false hopes of good coal being discovered on the "North Bank." From the neighbourhood of the Subansiri pieces of true coal were shown to the writer. The finders had an exaggerated idea of the value of their discovery, and refused to disclose the position of the main mass, further than saying that it came from the hills some considerable distance away. According

to the dip of the strata in the neighbourhood, the locus of this find, if genuine and if in the coal measures, ought to be situated some two or three miles east of the Dhol.

So general, however, is the association of coal and petroleum in Upper Assam that the complete absence of "pungs," or oil springs, from the northern bank of the Brahmaputra must be accepted as strong negative evidence of the absence from the Sub-Himalayas of coal measures corresponding to those of Margherita. Coal seams of Damuda age we already know to exist there.

The general question of the age of the coal measures will be best considered after the evidence afforded by the overlying rocks has been examined.

Tipam Sandstone and Sub-Himalayan Series.

These rocks are typically developed about the low range of hills east of Jaipur, which suggested to Mallet the name adopted for this formation. They extend for many miles north and south, in the north-east rising up on the Patkai Range to nearly 7,000 feet and completely obliterating the older rocks. Like the other members of the Tertiary series along the Dihing River, they have a general dip to the heart of the main range. In their most characteristic development they are grey, or greenish-grey, speckled sandstones made up of quartz, felspar, a white mica, biotite, hornblende and chlorite, the last when abundant giving to the rock its greenish colour. They weather to dull grey boulders, and occasionally, by decomposition of the ferro-magnesian constituents, to a rusty brown. Thin bands of clays and shales—brown, green, and bluish grey—occur, but are rare. Lignite bands are not uncommon, and the formation as a whole is characterised by the abundant presence of semi-carbonised, semi-silicified wood. False bedding is everywhere apparent, the lines of bedding being often picked out on weathering by thin strings of half-inch pebbles. As a rule, coarse conglomerates are absent.

A good section of the rocks is exposed in the Janglu Pani, a small tributary of the Dihing below Margherita. Here they are composed of the typical homogeneous sandstone, with harder, more argillaceous beds at long intervals. The general dip is S. E. and S. S. E. at 40° to 60°. At the northern end of the gorge through which the Janglu has cut its way, they appear—for the section is much obscured by jungle—to lie conformably on blue clays with carbonaceous

beds, which are certainly to be referred to the coal measures. Very close to the base of the sandstones is a seam of coal, which at its thickest part, and that is no more than two to three inches, appeared to be formed in the normal way. On following the seam some little distance up the nala to the Hathi Pung, it was seen that the supposed seam was in reality a coal conglomerate, being formed by an aggregation of rounded coal pebbles. Mallet [1] describes coal conglomerates that occur near the top of the Tipam beds and also in his Dihing series, but the horizon of the seam above-mentioned is very much lower, and unless there is a fault between the Hathi Pung and the gorge of the Dihing, for which assumption there is no evidence, we must conclude that it is some 2,500 feet at least below the base of the Dihing series.

Wherever seen, the coal measures appear to conformably underlie the Tipam sandstones and to merge into them by a series of gradually thickening beds of sandstone. The evidence of the above-noted coal conglomerate, however, shows conclusively that though there may have been no unconformity of stratification between the two series, there was yet an appreciable lapse of time, sufficient at least to allow for the elevation of the coal measures. It might also be inferred from the nature of the coal detritus in the Tipam beds that, geologically speaking, this interval was of no very great duration, for the coal of the coal conglomerate is generally lignitic, indicating that it was removed from the parent seam before the latter underwent those chemical changes that have added so greatly to its value.

There appears to be no very valid reason for the separation of the uppermost beds, the Dihing series of Mallet, from the Tipam sandstones. It is true that the pebbles of the Dihing beds are composed of a sandstone precisely resembling those derived from the harder and more argillaceous members of the Tipam rocks, but the similarity of the pebbles to the sandstones of the much older Disang series is equally well marked. The whole question of the separation therefore hinges on the identity of the pebbles, the beds themselves being practically conformable with the underlying strata.

On working along the sections of these rocks near the gorge of the Dihing above Jaipur, the younger rocks are found to be brought into lateral contact with, and indeed occasionally appear to underlie

[1] *Loc cit sup.*

the older beds. These and other apparent anomalies are best explained by the assumption of the presence of a series of reversed step faults such as are normal along the line of separation of an area at rest from one undergoing elevation due to tangential stress. The evidence in favour of these reversed faults has already been collated by Mallet.

The presence of rocks with lower Tipam characters in the Manabum Range, east of the Dihing River, has been mentioned. It is very probable that they extend some distance further east and wrap round the head of the Kamlang Valley, but they are certainly absent in the vicinity of the Brahmakhund and for some 25 miles to the north-west along the flank of the schists. Their first appearance on the north bank of the Brahmaputra would, judging from the outlines of the hills, appear to be in the vicinity of the old deserted Ahom walled city of Bishemnagar, and they certainly have considerable development at Nizamghat at the mouth of the Dibong gorge. Here they were examined only on the left bank, about two miles above the old Nizamghat stockade. Being in the practically hostile Abor country, the time available was naturally limited and was devoted to the economic, the main, aspect of the survey, so that here, as at the Manabum Range, neither dip nor strike were satisfactorily ascertained, all the sections seen being confused by the development of cross jointing. So far as could be judged from the landslips seen on the opposite range, the sandstone area covers at least the slopes on which are situated Dombuk and Membo, the principal Abor villages in the vicinity of the plains.

The hills immediately to the west of the Dibong were not visited during the present season, but an observation made by Medlicott in 1865 [1] shows that the characteristic sandstones are strongly developed due north of Dibrugarh, and that they there dip towards the hills. In the paper quoted an interesting discovery is recorded [2] of "a fossil elephant's tooth, found by Bryan Comber, Esq., in the gorge of the Deijmoo, north of Dibrugarh." Should the discovery be truly fossil, the specimen is unique from the Eastern Sub-Himalayas, but it would be rash to postulate the existence of a Siwalik or later fossil fauna from the evidence furnished by a single fragmentary specimen from a genus that abounds in the vicinity at the present day.

[1] Memoirs, Geol. Surv. India, Vol. IV, p. 393.
[2] *Loc. cit.*, p. 436.

In the neighbourhood of the Subansiri the typical sandstones attain a considerable thickness, and rise abruptly from the plain to heights of 2,000 to 3,000 feet, showing sheer cliff faces 600 to 700 feet high. The outermost beds as seen in the Kalia Joli, the Naubhanga, and the Virgua streams, all in the vicinity of the gorge, are pebbly conglomerates 10 to 30 feet wide and dipping north-west at 60° to 70°. The pebbles are well waterworn, range up to 4 inches in diameter, and are of rocks identical with those found in the river beds at the present time. On following the strata into the hills the dip gives place so suddenly to verticality, with a complete disappearance of the conglomerates, that it is necessary to assume that the latter have been brought to their present position by a fault. The sandstones throughout the section examined maintain an even N. W.—S. E. strike, but in the vicinity of Gayamukh, some miles within the gorge, they reverse to the S. W. Here also are intercalated in the sandstones thin bands of bluish-grey shales representing swamps on the ancient river banks, indistinct remains of vegetable matter being abundant. As in the Tipam Range, the sandstones as a whole are characterised by the presence of abundant fragments of semi-carbonised, semi-silicified wood.

In the Bhoroli River the same rocks have been mapped by La Touche.[1] There they had a considerable thickness with a general N. W.—S. E. strike and a dip varying from 65° N. E. to vertical.

There can be little doubt of the contemporaneity of these Sub-Himalayan rocks and of the Tipam sandstones. The series has now been traced in a practically unbroken line round the head of the Brahmaputra, and the lithological characters of the rocks on either side of the valley are identical. West of the Bhoroli, the Sub-Himalayan sandstones are continuous as far as the classic ground of the Siwalik Hills where their age is evidently Upper Tertiary. To the same period, therefore, must the Tipam sandstones be relegated. Further, since there is no evidence of a great unconformity between the Tipam rocks and the underlying coal measures, no greater age than Middle Tertiary can be assigned to the latter. This determination receives some confirmation from a consideration of the geology of the Dhunsiri Valley and the Mikir Hills, to the south-west, where a series of rocks, there little disturbed, shows a complete

[1] *Loc. cit.*

ascending section from the eocene nummulitics, through shales and coal beds equivalent apparently to the Disang group and to the coal measures respectively, to sandstones with silicified wood perhaps representing the Tipam series.[1] The only apparent objection to this classification is found in the exceptionally good quality of the coal at Makúm and Jaipur, it being far superior to that of Bengal, despite the greater age of the latter. It may, however, be shown, with some degree of probability, that this excellence is due to accelerated chemical action rather than to any great lapse of time.

Pleistocene River Terraces.

These are to be found only along the hills at the foot of the Himalayan chain and in the Upper Dihing Valley. They either have not been formed along the foot of the Patkai Range, on the left bank of the Lower Dihing, or more probably have been completely eroded in that locality. Elevated river gravels certainly do occur in this latter area, but at such an insignificant height above the present flood level as hardly to warrant the use of the term high level gravel. In the Upper Dihing Valley, though found everywhere along the course of the stream, they are yet best developed in the Dapha, the principal tributary. Here there are three terraces, 250, 160, and 140 feet in height, respectively, the surface of the highest, and therefore the oldest, being 1,000 feet above the level of the valley. The terraces are composed of the same rocks as are now found in the bed of the valley.[2]

Nothing so well developed as the above has been seen during the present season, and the best terrace section met with was that above Parghaut or Mishmighat, where the Brahmaputra leaves the foot of the hills. This terrace is only about 150 feet in height, and forms a spur running out into the valley. Good sections are exposed on two sides, on the north by the Tymi stream, and on the south-east by the main river. As will be seen from the accompanying plate a rude stratification is developed. The contained boulders are of the rocks found in the present bed of the Brahmaputra. A succession of terraces also occurs on the opposite side of the river on the way to the Brahmakhund, but is much obscured by jungle. A similar

[1] Memoirs, Geol. Surv. India, Vol. XXVIII, Pt. I, p. 91.

[2] La Touche, Records, Geol. Surv. India, Vol. XIX, Pt. II, p. 114; S. E. Peal, Jour. As. Soc. Beng., Vol. LII, Pt. II, p. 46.

terrace, due, however, not to the Brahmaputra, but to the local stream, is met with at the gorge of the Digaru, and another at Nizamghat, on the Dibong River. At the Subansiri the old terraces are not well preserved, but a remnant 100 feet high is exposed in the Virgua stream on the left bank of the Subansiri, and another as a low ridge jutting out into the plain at the head of the Dulung, a stream flowing east to the same river. At the Kakoi, beyond Kuddum, they are, on the authority of Mr. J. L. Alexander, well exposed. Hills of confused drift, 800-900 feet high, and obviously the product of the local stream, have been noted from the mouth of the Bhoroli.[1]

The exposure of these old gravels is due to an increase of the steepness of the slope of the river valley, a change which may be effected either by elevation of the head of the valley or by depression of the lower portion. In either case the result is the same—the deposits at the head of the valley are cut down until the natural slope under the conditions prevailing is reached. From the undisturbed nature of the drifts it is hardly likely that the change arose from elevation of the head of the Lohit Brahmaputra valley, and this conclusion is supported by further evidence which will be dealt with when treating of the alluvium of the valley. The superior height of the Dapha terraces in the Upper Dihing Valley, may, on the other hand, be possibly referred to the reversed faults with extensive "throw" which have been formed along the northern base of the Patkai Range in the process of mountain building.

Alluvium.

The alluvium of the Upper Assam Valley may be divided perhaps more markedly than that of any other Indian river into the two regions of *bhangar*, or higher land, and *khadar*, or low land subject to annual flooding. The former is naturally well developed at the head of the valley east of Dibrugarh, and also as a gradually narrowing fringe along the base of the hills on either side of the valley below Dibrugarh. The slope of the river beds in this area is considerable, as evidenced by the numerous rapids and by the strength of the current. This higher land, though formed in much the same way, is by no means equivalent to the *bhabar* of the Western Sub-Himalayas, and the only slope seen which might with justice

[1] Records, Geol. Surv. India, Vol. XVIII, Pt. II, p. 122.

be compared in degree to those of the north-west occurs in the bay of the hills on the right bank of the Dibong at Nizamghat. It is probable that much *bhabar* formed along the foot hills has been removed during the wanderings of the Brahmaputra over the plain, for though that river now pursues a comparatively straight course down the middle of the valley, it has in former times certainly assisted to form the terraces on the flanks of the Sub-Himalayas. There is indeed an old Assamese tradition that the Brahmaputra in ancient times flowed along the base of the hills in this area, and that its vagaries have been considerable we already know. As lately as 1821 its course at a part much nearer the sea was along the base of the Western Garo Hills, from which it is now separated by a considerable breadth of alluvium.[1]

Above Dibrugarh, therefore, the rivers are more or less confined to their banks, but below that station there is an ever increasing width completely under water during the rains. Practically the whole of the Subansiri drainage area in the plains is thus submerged, and there is at that period of the year no dry land between North Lakhimpur and Jorhat, a distance of 35 miles. The position of the high land may be fairly well picked out on a map by the distribution of tea gardens, which are of necessity situated on land not subject to flooding. Considering the silt-laden character of the Brahmaputra, and the distance, certainly 500 miles, of this portion of the valley from the delta, the low-lying nature of this area is distinctly anomalous. An explanation for this anomaly must be sought in a change of elevation of the whole or of some portion of the floor of the valley. It is clear that in the area under question the land cannot be rising, and it is equally clear that it is not stationary, for in that case, with a river carrying so much solid matter in suspension as the Brahmaputra, the level of the adjacent plain would soon reach the flood level mark and would rapidly be carried far beyond that by the abundant vegetable growth of the country. It must therefore be assumed that the floor of the valley is here sinking. For this assumption there is some evidence. Outside the area we know from the evidence of the Calcutta bore-hole that that portion of the valley has sunk many hundreds of feet. Within the area we are also able to find confirmation of the truth of the general assumption. At Pathalipam, on the Subansiri, a flood of some years ago washed away a considerable acreage of tea land, exposing, ten

[1] Geol. Trans., Series II, Vol. I, p. 132, 1824; *Ib.* II., p. 393, 1829.

to fifteen feet below the former level, the remains of an old forest with stumps of trees three feet in height, projecting from a bed of blue clay. The stumps have been identified by Mr. J. L. Alexander as belonging to the still local *bhi* (*Salix tetrasperma*), a tree of the willow family affecting swamps. It is hardly probable that any portion of land so close to the hills and to the Subansiri, and therefore subject to flooding, ever stood at that depth below the ordinary level of the adjacent river banks, and we must conclude that the swamp has been considerably depressed. Further evidence of depression appears to be furnished by the gorge of the Subansiri. This is a deep, narrow rift, 800-900 feet above water level, and in one place at least more than 360 feet (the length of a mahaseer fishing line) below it. It is four miles from the mouth to the first rapid at Gaya Mukh, and it does not appear conceivable that any river, even a Himalayan river, could excavate its bed to such a depth and for such a length, by the mere force of its current. On the assumption, however, that the excavation took place when the bed of the valley was higher, the facts at once are reconcilable with our knowledge of the erosive power of rivers. Still further confirmatory evidence of depression is afforded by the fact that the neighbouring streams in the sandstone have all cut their valleys back to an almost perpendicular cliff up to which the débris-laden valley floor slopes very gently. The evidence in favour of recent depression is thus, taken on the whole, fairly conclusive.

The Formation of the Assam Valley.

While from the extremely limited data at hand it can serve no useful purpose to indulge in lengthy speculations on the fascinating problem of the formation of the Assam Valley and its adjacent mountain ranges, there are yet several reasonable deductions to be drawn even from the scanty knowledge in our possession. The main facts on which the history of the valley must be based may be briefly summarized as follows:—

(1) The presence of Upper Tertiary sandstones at a considerable height (maximum, 6,900 feet) on the Patkai Ranges, and on the foothills of the Eastern Himalayas.

(2) Their complete absence, so far as is known, from the Miju Ranges.

(3) The disturbance, general uptilting, and reversed faulting of the Tertiary rocks on each side of the valley.

(4) The horizontality of the Tertiary rocks of the Shillong plateau.

(5) The presence of crystalline and metamorphic rocks beneath the Shillong plateau, and, in places, as at Tezpur, along the floor of the Assam Valley.

Generally speaking, the Upper Assam Valley lies N. E. and S. W. between two fairly parallel mountain chains. Of these, the Eastern Himalayas are formed of a massive crystalline and metamorphic core, with a comparatively narrow southern fringe of sedimentary rocks, of which the outermost—the Sub-Himalayan sandstone—is also the youngest and the thickest. The Patkais, on the other hand, have, as an apparent core, a series, well developed in Manipur, of unfossiliferous slates and sandstones of indeterminate age, but which are possibly as young as Lower Tertiary. Over these there lies an immense deposit of Upper Tertiary sandstones. The head of the Assam Valley is closed by the crystallines and metamorphics of the Miju Ranges which lie across it at right angles to the trend of the two lateral ranges. Almost across the mouth of the valley is the Shillong plateau running obliquely from east to west and deflecting the Brahmaputra from its south-westerly to a westerly course.

The first indication of the conditions existing in this region in early Tertiary time, than which we need go no further back, is afforded by the Nummulitic limestones of the Shillong area. These are of course marine, but the thinning out observable to the north and to the east indicates an approach to the old Eocene shore line in those directions. To the east of this Nummulitic Sea was low-lying land which, at a slightly later period in geological history, was submerged and received a thick deposit of muds and clays, was again raised sufficiently high to admit of a luxuriant vegetation, and was finally depressed until its vegetation was covered by hundreds of feet of muds. These are the coal measures of Assam, and extend along the south of the valley from the Dihing River to the Shillong plateau. Of their lateral extent at the time of their formation or at the present time we are absolutely ignorant. To the north they have been truncated by the great reversed fault which runs along the south side of the Assam valley, and in the valley itself they have either been completely eroded or are buried beneath the alluvium. To the south they dip into the heart of the Patkais, and of these mountains we know no more than the outer fringe.

The muds and clays of the coal measures were, apparently without suffering intermediate denudation, now being buried beneath the enormous gravel deposits that the silt-laden rivers of the north—the ancient representatives of the Subansiri, Tsanpo, Dibong, and the Lohit Brahmaputra—were pouring in from the higher lands of what is now Tibet. These gravel beds stretched along a plain the width of Burma, from the Himalayas in the north to Prome in Pegu in the south, and must have borne a considerable resemblance to those of the present Gangetic Valley. Everywhere they are characterised by the presence of silicified wood and of lignite nests and streaks, in either case the relics of the river drift-wood. So vast a deposit points, if not to the presence of several river valleys, at least to the presence of huge tributaries, and to the probability that the drainage of all Tibet then, as now, tended to converge to a point at the head of the Assam Valley.

The eastern boundary of the ancient valley ran due south from the Miju Ranges along the flanks of the Burmese crystallines and metamorphics to nearly as far as Rangoon, with here and there an irregularity caused by the projection into the plain of older tertiaries. It would appear also that the major portion of the great land extension into the Bay of Bengal, which the Irawadi is now continuing with comparative slowness, was laid down at this time and with the spoils of the Tibetan highlands.

The western limit of deposition was, on the other hand, the sea; the coast line then running across the Shillong area to Manipur. Both in the Western Gáro Hills[1] and at Sámaguting in Manipur,[2] there have been found marine fossils of an age not differing greatly from the time of the deposition of the river gravels. The thinness and patchy nature of the Upper Tertiary sandstones of the Shillong area would indicate that this area, for a time at least, served as a land boundary to deposition.

Prior to this period the physical history of the Eastern Himalayas must be represented by a blank, relieved only by the knowledge that a restricted portion was low-lying land in Damuda time. Now, however, saw the commencement of those earth movements, the continuation of which has furnished one of the greatest of the world's mountain chains. In obedience to tangential stresses in the

[1] Geol. Trans., Series II, Vol. I, p. 132 (1824).
[2] Memoirs, Geol. Surv. India, Vol. XIX, p. 226 (1883).

earth's crust an uplift took place, at first, no doubt, general over the whole Eastern Himalayan area and unattended by any great disturbance of the strata. So much at least is indicated by the undisturbed condition of the Shillong tertiaries. With continued uplift two main, and perhaps complementary, directions of pressure become distinguishable, the one acting on the Himalayas from the north and north-west and the other on the rocks of what are now the Patkais and Arâcan Ranges from the south-east and east.

It would appear that the Shillong area was soon separated by faulting from the rocks to the east. On the south of that region the strata are sharply bent over along an east and west line into a uniclinal fold, which is probably merely the expression of an extensive fault. The Shillong plateau owes its isolation and its consequent freedom from disturbance to the possession of a rigid base of crystalline and metamorphic rocks, and since there is evidence of the floor of the Assam Valley being composed of the same rocks, it is reasonable to suppose that there also a similar resistance was offered. We have considerable evidence of reversed faulting on each side of the valley, and on the foregoing assumptions the bottom of the Assam Valley may be imagined as a broad truncated wedge of immovable crystallines and metamorphics offering resistance equally to pressure in either of the abovenoted directions.

The deflection of the Brahmaputra and kindred rivers from a southerly course across Burma to a westerly one along the base of the Himalayas had taken place with the initial uplift of the Patkais and the trend of the Assam Valley was now fully determined.

Continued stress on the younger rocks found a small measure of relief in overriding the floor of the valley but a far greater in the development of earth folds. For the structure of the Himalayas and of the Patkais is not simple, as has been tacitly assumed, for example, by Suess.[1] On the other hand La Touche,[2] Godwin-Austen,[3] and Peal[4] all show that though the outermost rocks of the Himalayas dip north-west and those of the Patkais south-east, yet in either case, as the mountains are penetrated, the dip rapidly steepens and is soon

[1] La Face de la Terre, Tome I, p. 594.
[2] Records, Geol. Surv. India, Vol. XVIII, p. 122.
[3] Jour. As. Soc. Beng., Vol. XLIV, p. 37.
[4] Jour. As. Soc. Beng., Vol. XLI, Pt. I, p. 9.

reversed, and that not once, but several times. This fact disposes of an otherwise legitimate inference from the data of Suess, *viz.*, that since the opposite sides of the valley show reverse dips in similar rocks, the valley has therefore been excavated along an anticlinal axis. This inference is further negatived by the absence of the tertiary sandstones high up on the western flanks of the Miju Ranges, where, had they ever been deposited, they would certainly have escaped denudation, for the streams flowing in from that side are few, are comparatively short in course, and from their torrential character and steep fall to the Assam Valley have cut back for themselves deep gorges. So far indeed has this action proceeded in the case of the Lohit Brahmaputra, or Zayul, that it has "captured" one of the upper valleys of the Irawadi, thus breaking into the great meridional river system of Upper Burma and Tibet.

While the Brahmaputra has no doubt considerably eroded the Tertiary sandstones along its course, yet their almost complete absence from the valley surface may be due to a depression of the floor carrying down these rocks below the level of erosion and leaving no more than the Manabum Range, near the head of the valley, as evidence of their former surface extension. The protrusion of granitic rocks through the alluvium of the valley in the vicinity of Tezpur is far from clear evidence of the erosion of the Tertiaries, for it has already been shown that this area was not in the direct line of deposition, and that for some time at least it was above the valley level, bearing indeed to the Gangetic Sea on the one side and to the alluvial valley on the other much the same relation as the Arakan Yoma mountains at the present day bear to the Bay of Bengal and to the valley of the Irawadi respectively.

The already mentioned difference in height above sea-level of the river terraces at the Brahmakhund and of the Dapha Pani and the Upper Dihing cannot be accepted as altogether conclusive evidence of relative movement in comparatively recent times. The latter terraces may have been portions of extensive river flats formed near the head of the valley in much the same manner as the *patthar* above Kumki exists at the present time, and may never have formed portion of the Assam Valley alluvium as those at the Brahmakhund certainly have done.

There now remains to be considered a point of considerable interest. It will be seen on inspection of the accompanying map that,

On approaching the Miju Ranges, the Patkais lose the curve that they have carried through nine degrees of latitude and turn sharply to the east and south-east. The trend of these mountains being generally an expression of the strike of their component rocks, the latter may with confidence be assumed to turn also to the east. The observed strikes in this region are scanty but seem rather to support the assumption than otherwise. On the little known northern side of the Brahmaputra a similar rapid change in the curve of the Himalayas as they approach the Miju mountains seems to take place, but in this case the deflection is towards the north.

It would appear to the writer that this phenomenon is in either case due to the same cause, *viz.*, to the retardation offered by the flanks of the immovable Miju Ranges to the horizontal movement of the plastic Tertiary rocks urged forward in obedience to the great tangential earth stresses that have formed these two mountain chains. With actual contact with the flanks of the Miju Ranges the sandstones are much disturbed and broken, as is shown by the varying strikes and dips noted by La Touche in the Upper Dihing Valley.[1] The phenomenon is indeed exactly paralleled in faulting in stratified rocks. The first indication of approach to a fault is often the gentle bending of the strata, the curve rapidly increasing with proximity to the fault, the bed finally finding relief in minor fractures along the fault line. The disturbance of the Tertiaries noted above corresponds closely with these minor dislocations. The movement of the strata in the case of the Patkais is horizontal instead of vertical, otherwise the difference is merely one of degree.

The Shillong plateau, as distinguished from the floor of fundamental rocks that are assumed to run up the Assam Valley, has exercised little retardent action on horizontal movement and has apparently in nowise influenced the direction of the Patkai Ranges. It is true that at first sight the parallel sandstones ranges of Hill Tipperah, being advanced somewhat beyond the main arc of the range, seem to be the result of an actual forward and horizontal movement due to the absence of the resistance of crystalline and metamorphic rocks immediately south of the Shillong plateau; but, if the past history of that area and the present condition of these ridges be considered, the explanation is clear. In Eocene and even in late Tertiary time a Gangetic Sea existed to the west, and there has consequently never

[1] Records, Geol. Surv. India, Vol. XIX, Pt. II, p. 114.

been any opposition to the development of normal mountain structure in that direction. Further, the Hill Tipperah ranges themselves show a decided decrease in height to the west, eminently suggestive of a decrease in intensity of stress. These advanced ridges are therefore merely the normal minor foldings in advance of a mountain chain, their absence further north being due partly to erosion, but mainly to buttressing against the older immovable rocks.

Finally, it should now be abundantly apparent that the Patkais and the Himalayas, in their later growth at least, are of contemporaneous development, and are, both orographically and geologically, entirely distinct from the great meridional mountain system of Upper Burma, Tibet, and Western China, and that, despite the assumptions of geographers who have been misled by sketchy and necessarily imperfect maps, the termination of either is practically coincident with the head of the Assam Valley.

THE AURIFEROUS OCCURRENCES OF ASSAM, *by* J. MALCOLM MACLAREN, B.Sc., F.G.S., *Mining Specialist, Geological Survey of India.*

Introduction.

From time to time during the past two decades spasmodic and invariably abortive attempts have been made to resuscitate the ancient gold industry of Assam. These attempts have generally been based on the knowledge that the rivers of Upper Assam yielded to the former Rajas, by a species of *corveé*, it is true, very large quantities of gold; and also to some extent on the knowledge that with modern dredging and hydraulicing appliances a gravel containing a very small proportion of gold can, under favourable circumstances, be made to yield profitable returns, though the same gravel might be quite unworthy of the attention of the individual washer working without the aid of extraneous power. With what prospects of financial success these projects were conceived, and the causes that have contributed to their failure, it is the object of the following to indicate.

Historical.

The first mention of the gold of Assam is contained in the Sabha Parva, the second book of the Mahabharata. Its enumeration of the gifts brought to Yudhishthira, the son of Panda, runs:—"Again in the eastern portion of the Himalayas the people on the banks of the Lauhîtya river bring sandalwood, agallochum, the fragrant wood called kalyaka, skins, female slaves, curious foreign birds and beasts, and gold collected in the mountains."[1] This Lauhitya is undoubtedly the modern Brahmaputra, both the Lohits, the Chacra Lohita or greater Lohit, and the Cshudra Lohita or lesser one, being mentioned in the Matya-Purana.[2]

The famous traveller, Jean Baptiste Tavernier, writing about 1670 from information that must have been supplied to him, for he never visited Assam, says:[3] "The Kingdom of Asem is one of the best countries of all Asia, for it produces all things necessary for humane subsistence, without any need of foreign supply. There are

[1] Wilson, Ariana Antiqua, p. 135.
[2] *Vide* Wilford, Asiatic Researches, Vol. XIV, p. 425.
[3] Pt. II, Book III, Cap. XVI, p. 178 (1684 Ed.)

in it mines of Gold, Silver, Steel, Lead, Iron, and great store of Silk but coarse.....As for their Gold they never suffer it to be transported out of the Kingdom, nor do they make any money of it, but they preserve it all in Ingots which pass in trade among the Inhabitants, but as for the Silver the King coins into money as already described."

Of the popular estimate of the wealth of Assam at that time we obtain a further glimpse from the 'Álamgírnámah of Mahomed Kazim, the historian who accompanied Mir Jumla, Aurungzebe's general, in his invasion of Assam (1660-1662):—"Gold and silver are procured here" (speaking of Lower Assam) "as in the whole country of Asam, by washing the sand of the rivers. This indeed is one of the sources of revenue. It is supposed that 12,000 and some say 20,000, are employed in the occupation; and it is a regulation that each of these persons shall pay a fixed revenue of a tola of gold to the Rajas."

In other Mussulman histories of the same period are also contained references to Assam gold. In the Padisháhámah (p. 68):— "Asam.....is a large country...producing...also gold of inferior quality which sells at half price:"[1] In the Fathiyah i 'Ibriyah of Shihabuddin Talish (1662-1663)[2]:—"Gold is found in the Brahmaputra; about ten thousand people are employed in the washings. Each man on the average makes a tola of gold per annum and hands it to the Raja. But the gold is not fine and sells for 9 or 8 rupees per tola."

The auriferous deposits of Assam appear to have early attracted the attention of Europeans, for Ravenshaw, in 1833[3] mentions that 40 maunds of Brahmaputra sand that had been sent by Mr. W. Cracroft some time before, yielded a concentrate of 396 grains, of which 147·3 grains proved to be magnetite. The residue on treatment gave 1·9 grains of gold, or at the rate of 1·3 grains per ton.

The first detailed description of the state of the industry is, however contained in a paper drawn up, obviously as the result of official instructions, by one Muniram, a Revenue Sheristadar. Written in 1838, the information contained therein, being drawn mainly from the older sonwals or gold-washers, will probably truly represent the state of the industry for at least fifty years prior to the enquiry. Muniram states[4] that during the time of Raja Rajeswur Singh (1751-1768)

[1] Jour. As. Soc. Beng., Vol. XLI, p. 55.
[2] *Loc. cit.*, p. 78.
[3] Jour. As. Soc. Bengal, Vol. II, p. 266.
[4] Jour. As. Soc. Bengal, Vol. VII (1838), p. 621.

the sonwals of Upper Assam alone used to give 6,000 or 7,000 tolas (2,250 to 2,625 ounces) in addition to the *mohia* or tax that was levied on them. In Raja Gaurinath Singh's time (1780-1794) the amount contributed had fallen to 4,000 tolas (1,500 ozs.) and further still under the Bor Gohains (circa 1816) to 2,000 tolas (750 ozs.). While admitting that some trifling inaccuracies may have crept into his estimates owing to the absence of documentary evidence, Muniram reiterates that "it is a positive fact that some 4,000 tolas at the very least were annually received by the Assam Raja." The number of washers had suffered a like diminution. A careful compilation shows that while "during the time of Government"[1] (1826-1833) 457 *gotes* of *paiks*, or individuals, (a gote is a party of four) were in existence, and taxes had been paid by at least 400 gotes, these had "in the Raja's time" (Purandar Singh, 1833-1838) diminished to 184½ gotes, and even to this enumeration the *kheldars* or headmen, by whom the tax was probably directly paid, had strongly objected, affirming that there were no more than 150-160 gotes in all.

The tax paid by each sonwal was nominally half a tola of gold, but as it had to pass through many hands before being deposited in the Raja's treasury, the amount actually paid by, or rather for, each paik was as follows:—

Original tax	½ tola
Melting charges:—	
For very clean gold . . . 3 ratis per ½ tola = 1/32 tola	
For moderately clean gold . 4 „ „ „ = 1/24 „	
For badly cleaned gold . . 6 „ „ „ = 1/16 „ .	1/16
Various perquisites:—	
Phokuns and Burias (military and civil commanders), 1 tola in 20	1/40
Teklas and Burras (peons), ½ tola in 20 . . .	1/80
Bhundar Kagoti (Phokun's writer), ¼ tola in 20. . .	1/160
Servants of the Raja's household. These were the Chung Kagoti (the Raja's treasurer), the Bhundari Likira (the assistant treasurer), the Pachoni, (chaprassi) and the Kukura Chowa Burra (orderly), and their share was at the rate of 1¼ tolas of silver for each tola of gold.	
Assuming a ratio of 20: 1	5/160

the whole making a total of 51/80 tola of gold. The additional

[1] After the Burmese War of 1826, the province of Assam was administered for seven years by the East India Company, which then handed over government to the former Raja, Purandar Singh. Owing, however, to his incapacity, it was found necessary to resume direct administration in 1838.

27·5 per cent. thus imposed on account of taxes, etc., must under the circumstances be deemed extremely moderate, but as one column of Muniram's enumeration is devoted to those sonwal paiks who had run away and were masterless, it was probably policy rather than any feeling of compunction that restrained the exactions.

The sonwals or gold-washers appear to have contained representatives of all the classes and castes then found in Assam, but were mainly recruited from the Behiahs (a tribe of Ahoms) and from the Kacharis. With the exception of the Sadiya Kacharis, who washed under the special direction of the Raja, all other sonwals were subject to the Phokuns, Burias, or other minor chiefs under whom they happened to be dwelling.

Supplementing Muniram's paper and published at the same time were extracts from reports by Captain Hannay, who selects the Bhoroli, the Subansiri, the Desoi, and the Janglu Pani as being the most important gold-bearing streams. The gold of the last two rivers was so much prized for its colour "that the jewels of the Raja's family of Assam were invariably made up from what was collected in them."

With the resumption of direct government in 1838, the head tax on sonwals was abolished and a land revenue tax substituted. From that time onward the industry rapidly declined, the younger sonwals doubtless obtaining more easily from the fields than from the rivers the amount necessary for rent. The Government revenue from gold was obtained by farming out the annual right to wash to the highest bidder. In the year 1851, the Dihong was estimated to produce 40 to 50 tolas, and the right to wash was sold for Rs. 80. There, however, the washers were subject to the extortions of the Miris and of the wilder hill Abors, the former contenting themselves, if modern inhabitants are to be believed, with two annas' weight per tola or 12½ per cent., while nothing less than the whole satisfied the latter.

Urged no doubt by the decline in revenue from the gold washings, and probably still more by the wave of excitement that swept through the civilised world on the discovery of gold in California in 1849 and in Australia a few years later, the Government of the day, in 1853, deputed two officers—Major Hannay and Captain Dalton—both peculiarly well qualified for the work—to examine and report on the auriferous deposits of Assam. Their attention was naturally first directed to those rivers which had been famous gold producers

under the Assam Rajas, and during the cold season of 1852-1853 the Janglu and Sisi streams were visited. The Janglu was even then deserted and had been so for many years. Captain Dalton was assured that the stream was the abode of evil spirits, whose good will it was necessary to obtain before commencing washing operations. As the propitiatory offerings cost more than the value of the gold obtained, the place was eventually abandoned by the native washers. Certainly the gloomy, densely-wooded and fever-haunted gorges of the Janglu at once account for the belief in evil spirits, and it is natural that in such a place the increasing poverty of the deposit should be ascribed to malignant influences.

After examining the Janglu, Major Hannay and Captain Dalton proceeded to the Sisi, flowing from the Abor hills in the north, and joining the Brahmaputra below Dibrugarh. The Sisi villagers appear to have worked the deposits in the months of January, February and March, and then only for a week or a fortnight, during which time, if they were fortunate, they might obtain sufficient to pay their revenue taxes, the result of a day's washing being occasionally 20 grains. Captain Dalton estimated the average yield from the gravel treated at 15 grains per ton, and the total yield for the season at ¼ seer (15 ozs.). The whole of the Lakhimpur district in 1853 furnished 10 seers, or 300 ounces, of gold made up from the following streams[1]:—Subansiri, 2 seers; Dihong, 2 seers; Brahmaputra, ¾ seer; Dihong, ¾ seer; Sisi, ¼ seer; and others from ¼ to ½ seer each. The selling price of the unrefined gold was then from 14 to 15 rupees per tola,[2] the Brahmaputra gold being much lower in value than that from the northern rivers.

The explorations commenced in 1853 were continued during the following season in the Lohit Brahmaputra and in the Noa Dihing, which breaks away from the Buri Dihing at its debouchure from the hills and flows north to join the Brahmaputra above Sadiya. Traces of gold were found in the Brahmaputra as far as the Brahmakhund, but in no case were the deposits rich or extensive. Trials were made at the Guri Mara, an island in the main river opposite the Chunpura outpost. Here were washed in two days 456 maunds, or 16¾ tons, of gravel, for a total yield of 158 grains, or nearly 10 grains per ton. It appears, however, that the total amount of gravel available

[1] Jour. Roy. As. Soc., Vol. VI, p. 511.
[2] A tola = 7½ dwts. = ½ oz.

was limited, for, being late in the season, Captain Dalton could wash only in those places left undisturbed by the Sadiya washers. It further appears that the best seasons were those that succeeded very heavy floods, and even then a *duruni*, or washing trough, could not be expected to yield more than 2 annas weight per diem. As each duruni required at that place four men to work it, this represents a gross yield of only 8 annas worth per man per diem.

An examination of the Noa Dihing was then made, and though the extreme fineness of the gold rendered it a matter of great difficulty to treat the sands effectively, these washings are notable for having furnished a comparatively considerable quantity of platinum, and also a few grains of iridosmine, though the latter were not distinguished from the platinum until thirty years later.[1] The season's work was closed with the examination of the Dihong. At the spot there selected for trial, *viz.*, Sibia Mukh, 150 maunds or 5½ tons gravel yielded to native washing methods 90 grains of gold, or at the rate of 16½ grains per ton. The amount of gravel available is not stated, but was probably limited.

For many years subsequent to 1855 the annual rights of washing were submitted to auction, but the amounts offered becoming less and less the practice was at length discontinued. In 1874-5 the rights realised only Rs. 7, and in following years even less.

The decline and final disappearance of the gold-washing industry in Assam was due to a number of causes, of which the closing of the Subansiri to native washers in the interests of a proposed systematic exploitation, the poverty of the gravels, the appreciation of labour, and the extortions of the Marwari traders, or Kaiyas as they are called in Assam, appear to have been the most active. As already indicated, the old sonwals were compelled to pay their tax in gold, and in poor years each would naturally work no longer than was necessary to furnish his quota, so that the former produce of Assam must be looked on rather as a measure of the number of washers in the country than of the richness of the deposits. This assumption is confirmed by the fact that prominence is given by the early writers to the number of sonwals and not to the quantity of gold obtained by them, the latter factor being apparently regarded as bearing a fixed and definite relation to the former. Even in the days of the Assam Rajas, the number of sonwals had commenced

[1] Mallet, Records, Geol. Surv. India, Vol. XV (1882), Pt. 1, p. 53.

to decrease, probably because it was found more advantageous with the then increasing facilities for trade with European nations, to employ labour in the cultivation of the natural vegetable products of the country and to barter these for the desired gold than to obtain the same quantity of gold with greater labour from the rivers. Finally, it is certain that in the majority of cases the labour was not voluntarily given to the pursuit, for the 600—700 individuals enumerated by Muniram in 1838 had fifteen years later almost completely ceased operations. With the great appreciation of native labour attendant on the first tea "boom" of 1859-1862, gold-washing may be said to have disappeared. The sons of the old sonwals, on being questioned on the subject, invariably reply that the washings were never profitable except on the Subansiri and on the Desoi, and that they were abandoned because the younger sonwals could make more money by the cultivation of the soil coupled with occasional work on the tea gardens. On the Subansiri, which is certainly, for the native washer, the richest of all the Assamese rivers, the sonwals declare that it was only the direct prohibition of Government that compelled them to cease operations. But even there the greater part of the gold won was devoted to the payment of rent.

The method of farming out the rights to wash imposed a heavy tax on the unfortunate sonwal. These rights were generally bought for a small sum by one of the *amlah* or minor court officials, or by a hanger-on about the court, who naturally exacted as much as possible from the individual sonwal. In order to pay the rent, and to buy the quicksilver (at Rs. 3-4 per tola) necessary for his work, the sonwal, invariably the poorest of the Assamese, was forced to hypothecate to the Kaiya his whole season's output of gold, receiving no more than Rs. 8—10 per tola for what was worth in the bazar Rs. 16—17. Moreover, owing to the method of retorting the amalgam, the whole of the quicksilver employed in the process was lost, a loss certainly not less than Rs. 4—6 per tola of gold recovered.

Concessions have from time to time been granted to European speculators over various rivers in Assam, but, with the exception of the Subansiri, no serious work has been done and no great amount of capital has been expended. Attention was first directed to that river in 1884 by the publication[1] of assays crediting the gravels with

[1] *Englishman*, 2nd June, 1884, where the amount is stated in error as 26 ozs.; also Records, Geol. Surv. India, Vol. XVII, p. 192.

a value of 52 ozs. per ton, but hopes founded on these values were soon dashed to the ground by the discovery of the fact that the assays were made on concentrated sands resulting from the washing of large quantities of gravel.[1] In 1899, a company, composed mainly of tea planters, was formed with a capital of a lakh of rupees for the exploitation of the Subansiri. The operations of this company were, during three years, entirely confined to prospecting, and Rs. 70,000 were spent for no more definite result than a hazy idea that on the whole more money was necessary to prove the ground. Shortly afterwards a fairly systematic attempt, but on a small scale, was made to prove the bar at the foot of the Derpai pool above water level. In 1904 a concession was granted to a member of the original company. So far no work under this concession has been done on the ground, the energies of the concessionaire being devoted to endeavouring to float a company on the London market with a capital of four lakhs of rupees, or more than £25,000.

Native Methods of Washing.

As a general rule washing operations were formerly carried on only during the cold season, when the rivers and streams were at their lowest, but many of the Kachari washers washed during the rains when a sudden fall in the stream exposed gravels that had been subjected to the stronger currents. A spot was always selected where some concentration had taken place, as the beach below or opposite to a gravel bank in course of erosion. After preliminary trials by washing in a long bamboo scoop to determine the quantity of gold and the depth of the gravel, the overlying sands were removed either by a large wooden scraper drawn by two men and pressed down by a third, or, preferably, by damming back a portion of the stream and directing its flow over the sands to be washed away. The latter practice was invariably followed in the smaller streams. The flow of water was often continued after the gravel bed had been reached in order to concentrate the gold as much as possible before washing

[1] The explanation of this apparently high yield is the following: "Eight washers were selected, sixteen men being employed to dig and carry the gravel, supplying each washer with 400 lbs., or in all 3,200 lbs. From this about ½ lb. of concentrates were obtained yielding on treatment with quicksilver 4½ grains of gold or a little more than 3 grains per ton." It was a sample from this concentrated sand that yielded at the rate of 52 ozs. per ton, *Mining Journal*, Vol. LVII, p. 1399 (1887).

by hand. Where the gravels were exposed on the surface somewhat above the stream level, they were, to gain the same end, carried in baskets to the natural sluice made by confining the waters of the stream to a narrow channel. After a sufficient quantity of concentrated sands had been collected in the sluice, the waters were diverted to a similar parallel channel, where washing took place whilst the concentrated sands were being removed from the first channel to the washing trough or *duruni* (also termed *durani* and *dorongi*). As used at the present day, the duruni is a wooden trough 4 feet 2 inches long, 16 inches wide, and 4 inches deep, with a bottom for the most part flat, but sloping up longitudinally for the last nine inches of the upper end. The two sides are 3 inches high and ½ inch thick, but towards the lower end as they curve towards each other, they are thickened to 1½ inches. The opening left at the bottom is 2 inches wide. In the median line at the upper end is a semi-fusiform groove, 9 inches long and 1½ inches deep, into which the gold is finally worked. The wood employed in the manufacture of the washing trough is either poma (*Cedrela toona*) or makai (*Shorea Assamica*). In use the duruni is supported on three large stones, the upper end being slightly raised in order to accelerate the flow of water. The gravel which has been scraped from among the stones by means of a pointed stick and a basket (*kuki*) is sifted through a bamboo sieve (*bichana*), 18 inches wide and 24 inches long, which is placed over the upper end of the duruni. The large stones thus collected are removed from time to time by simply throwing off the *bichana*. The sand is assisted through the sieve by water poured from a bottle-shaped gourd (*lao*) held in the right hand, while the left hand is stirring up the finer sands towards the head of the trough. The vertical motion of the right hand and the horizontal reciprocating movement of the left is precisely that necessitated in the use of the Australian cradle. Stirred up by the left hand the lighter sands pass off with the water through the end opening, leaving the black sand with the gold. After washing a *shia*, or 40-50 baskets of sand, an amount probably determined by the percentage of "concentrates," the supply of sand is discontinued and the washer sets himself to collect the gold within as small a bulk as possible, working the heavier constituents always towards the head of the duruni and finally into the groove above-mentioned. This residue is then washed carefully into a copat leaf or into a bamboo knot (*chonga*). From 25-30 shias constitute a day's work, and

at its conclusion the accumulated concentrates are further washed in the duruni in order to reduce the percentage of black sand as far as possible. They are then taken to the village and rubbed up by hand with quicksilver in an earthenware bowl (*soru*) until, in the language of the gold-washers, all the gold has been "eaten" by the quicksilver. Excess of quicksilver is simply removed by squeezing the amalgam in the palm of one hand by the forefinger of the other. According to Muniram, one anna weight of quicksilver for each expected tola of gold was used. This is probably incorrect and in the light of modern metallurgical knowledge would seem utterly inadequate for the purpose. At the same time the high cost of the mercury and its complete loss in the operation of retorting must have tended towards the greatest possible economy in its use. For these reasons, and also for another previously indicated, the use of mercury was not always practised. In that case the sonwal, after washing as clean as possible, separated with a little pricker of steel or of bamboo each individual grain of gold from the sands—certainly a most tedious and lengthy operation.

"Retorting," or driving off the quicksilver, is conducted in a most primitive fashion. The lump of amalgam is placed in the half of a bivalve shell, generally of a species of *Unio*, and heated in a fire of charcoal made from the wood of the nahor (*Mesua ferrea*). On the Subansiri the siah nahor (*Kayea Assamica*), a somewhat similar wood, is employed. When the shell has been reduced to lime and the quicksilver driven off, the residue is taken up on a spoon and thrown into water, the gold falling to the bottom. In former days in the case of the colour not proving satisfactory, the gold was mixed with burnt clay and salt, and reheated, a process which generally proved efficacious.

The duruni appears to have been the only washing machine employed by the Assamese sonwals. The Singphos, however, used a circular and an oval wooden tray, the latter perhaps resembling that of the Ghasis of Chota Nagpur. So universal is the disappearance of the gold-washing industry from the Assam Valley that it was only after a prolonged search and many fruitless enquiries that examples of these primitive machines were obtained—the duruni from the Subansiri River at Pathalipam, and a circular Singpho tray from Chonkam on the Tengapani River, the principal village of the Kamtis, a tribe of Shans who have been settled in the north-east

corner of Assam for the last hundred years. The owner of the tray was an old and decrepid man who had abandoned his calling for nearly fifty years, and though the tray was cracked and worm-eaten, it was with the greatest difficulty that he was induced to part with this relic of his younger days. It measures two feet in diameter, and is centrically dished to a depth of 2½ inches, and is ½ inch thick. As far as could be judged from the meagre display of washing permitted by the infirmity of the old man, the method of use precisely resembled that practised in Chota Nagpur, as described in another place.[1]

Of the oval form of tray, no specimen was found, but Mr. F. J. Needham, Assistant Political Officer at Sadiya, to whom the writer is indebted for material assistance in the prosecution of his enquiries, and who has seen the gold-washings on the Hukong Valley, where similar trays are in use, says that it is deeply dished at the head for the retention of the gold and black sand, and is provided in the lower flatter portion with riffles. It does not appear that mercury was ever used with either of these trays, the washers being probably sufficiently expert in the separation of the gold from the black sand to dispense with its use.

In addition to the sands of the rivers, Muniram mentions two other sources of gold which call for some comment:—"The gold-washers in the Seedang River dry the moss and slime and then wash it in the usual manner." The Sedang River is a tributary of the Subansiri well within the hills. Considering the extremely fine character of the gold, this is at least a possible means of natural concentration, the moss acting as do the blankets in a sluice. If so, Muniram certainly omits an essential intermediate operation, *viz.*, that of burning the moss and slime to ashes before the final washing.

His third source of gold is much more problematical. "The sonwals of the Rydengia Phokun's Bhag go up to the hills and collect the *copat* which they burn for gold." The Rydengia were an Ahom tribe or *khel*, under the administration of a Phokun or chief, and the *copat* here mentioned is a species of the useful family *Zingiberacea*, with broad, tough and flexible green leaves, much used in Assam for wrapping purposes. Either then the story arose from the practice of burning the wrapping in which the gold dust was carried, and thus ensuring the recovery of every particle, or more probably it arose

[1] Records, Geol. Surv. India, Vol. XXXI, Pt. 2.

from the general custom of the sonwals of imparting as much mystery to their art as possible. As an example of the latter, the Miris now living on the Dihong River aver that it was the habit of the sonwals to hang cloths round their durunis and to allow no more than one Miri at a time to witness the operation of washing, declaring that the gold was so prone to taking offence that if several gazed at it, it would immediately disappear. In the territories of the stronger and more virile Abors and Miris this appeal to superstition may indeed have been adopted by the Assamese sonwals as an efficient measure of protection.

Since, so far as could be ascertained, the number of living sonwals who had formerly practised their craft is reduced to three, one at the Subansiri and two on the Desoi, their religious observances, in view of their early disappearance, are not without interest. The sonwals never commence washing operations at the beginning of the season or at an untried spot without first performing a religious ceremony. In the case of the Subansiri washer, it was necessary to supply the various materials required for the "puja." Three fowls, various articles of food, and a little whisky, in default of other spirit, sufficed. A fire was made, of necessity at the spot where washing was to be undertaken, and the old man with his two assistants sat facing it. The alcohol and food were thrown on the fire to the accompaniment of a monotonous chant, the words of which were simply "Tol Dongoria," an invocation of the name of the Deity, kindly translated for the writer by Mr. J. L. Alexander as "Under the Great One." The chant lasted about a quarter of an hour, each man meanwhile holding a fowl between his hands, with the thumbs on the back and the fingers on the breastbone. At the conclusion of the invocation the unfortunate birds were slowly squeezed to death between the hands. In former days, in addition to fowls, pigeons, ducks, and goats were sacrificed. The larger ducks and goats (which were invariably males) were sacrificed by placing their heads on a block of wood and slowly beating with a large round wooden billet. An essential feature seems to lie in the complete avoidance of bloodshed.

Not the least important part of the affair as practised before the writer appeared to be the eating of the sacrifice, the washers absolutely refusing to commence work until the ceremony had been appropriately rounded off by the consumption of the fowls.

The Desoi washers formerly practised the same ceremony, but

it was never their custom to sacrifice goats—the prospective profits from that river being probably too small.

EXPLORATIONS CARRIED ON DURING THE SEASON 1903-1904.

The Buri Dihing River.

The work of the present season was commenced on the Buri Dihing, which was ascended for some 40 miles above Margherita, the head-quarters of the Assam coal industry. It was not until Mokogaon, 16 miles from Margherita, was reached, that gravels suitable for washing were met with. From thence onward these gravels occurred in rapidly increasing quantity, until the base of the hills was approached, when they were replaced by boulder beaches containing little or no gravel. Gold was invariably found in the gravels, the best prospects occurring at the mouth of the Kherim Pani flowing from the Noa Dihing, and also at Makumdong, where another stream breaks through from the Noa Dihing to the Buri Dihing. As the hills were approached the gold became less and less in quantity, until in the Namrup, above the mouth of the Namchik, the dish showed only one or two "colours" and those of the smallest. The gold, wherever found, was extremely fine and flaky, so much so that, as a general rule, quite as good a show could be obtained by washing the soil shaken from the grass roots from the top of the *chaporis*, or flood-swept islands in the river bed, as from the gravels in the river bottom. Nowhere even in the best gravels did any prospect show more than a grain to the ton, and the majority showed very much less. Similar results were obtained in the Tirap, a tributary of the Dihing. In several places and notably above Jagun, the last riverside village on the Namrup, high banks of recent river conglomerate are exposed. These on washing rarely yielded more than two or three colours. So far, therefore, as can be judged from the washings made, the gravels of the Buri Dihing hold no promise of economic importance.

The Janglu Pani.

This small stream flows from the Tipam Hills and joins the Dihing River about eight miles below Margherita. For the final four or five miles of its course it winds through a flat sandy plain covered with dense jungle. On following the stream towards its source it is found to emerge from a gorge in hills of the Tipam

sandstone already described. The strata here dip S. E. to S. S. E. at angles of from 40° to 50°, and the course of the stream is at right angles to the strike, thus exposing a fairly good section of the rocks. Above the gorge, which is about 1½ miles in length, the course of the upper portion of the stream lies through a broad basin breached to the east. Two main tributaries join at the upper end of the gorge, the eastern being known, *par excellence*, as the Hone Jan—the golden stream—the western retaining the name of the Janglu Pani. A hundred yards above this junction the Hone Jan divides into three streams, at the spot known to the villagers as the Hathi Pung, a salt lick much frequented by wild animals. The Janglu Pani itself, about four miles from the junction, divides again into two main branches, which of course are again subdivided into mere rivulets as the circumscribing hills are reached. All these upper branches and tributaries flow over the flat sandy bed of the basin above mentioned.

From the foregoing it may be inferred that neither in the lower nor in the uppermost portion of the stream will gold be found—an inference borne out by the trials made.

In spite of the utterly unpromising appearance of the upper streams, it was considered necessary to make some trials there, since the Douanias of Powai Jan, the only village within five miles of the Janglu Pani, had positively asserted that all the washings had formerly been carried on at the head of the main western stream. The result proved them to be quite in error, but indeed none of the inhabitants of Powai Jan had ever seen the actual operation of washing, nor could they point out any definite spot where such had taken place, and the only real information in their possession was that the best place known to the old washers had been at a spot where three streams converged at a point, a condition found to be fulfilled at the Hathi Pung and which later operations showed to have been the only possible spot in which the old sonwals could have washed. It is a somewhat curious fact that though these villagers should have lost all knowledge of the methods and sites of washing, yet the same tradition that was told to Captain Hannay in 1838, *viz.*, that a huge lump of gold was once found by a fortunate traveller while making his way through the jungle, is still current amongst them.

It is, therefore, only in the gorge, and immediately above and

below it, that the waters are sufficiently strong to carry away the overlying sands and to concentrate the heavier and larger portions of the débris into gravel beaches. These, though they carry gold in every case, in very small quantities it is true, are yet so insignificant in quantity in the lower portion of the gorge as to be quite negligible. Work was therefore concentrated on the largest patch of gravel that could be found, and this was no more than 10 cubic yards in bulk. The pebbles composing the auriferous gravel were of quartz, quartzite gneiss, a white granite, and sandstone, the last obviously of local origin. The pebbles ranged up to two inches in diameter, and of the whole it was found that only about 45 per cent. would pass through a screen of ½ inch square mesh. An attempt was made to obtain a preliminary concentration by sluicing, but it was soon found that the gold was so fine that with the grade necessary to clear the sluice box (which was of necessity somewhat short) there was a danger of losing a considerable proportion of the gold. The sluice box was therefore abandoned and concentration was effected on a shaking table of the West Australian "jigger" type. The heavy black sand left behind amounted to nearly one per cent. of the whole. So fine were these concentrates that it was found all would pass through a 40-mesh screen, and only a very small portion, and that composed mainly of rolled garnet crystals, refused to pass through a 60-mesh screen. In all the washings from the Janglu Pani and from the Dihing River a heavy white sand was left behind in the dish after all the garnets and magnetite had been removed. This on examination proved to be composed of extremely small zircons, together with a few grains of topaz.

The gravels were tried in bulk in various places to confirm the dish tests. The two following results are typical:—Gravel bars containing 10 cubic yards and $2\frac{2}{9}$ cubic yards yielded 1·1 grains and ·4 grain, respectively, representing in either case, after allowing for the greatest possible amount lost in washing, about $\frac{1}{5}$ grain per ton!

The quantity of gravel available is exceedingly small, certainly less than 200 cubic yards being exposed in the bed of the stream throughout its whole course. As a general rule, the deposits of gravel above the confluence of the two main streams are no more than a few cubic feet in content, and are often composed almost entirely of sandstone pebbles, a sure indication that they contain a very small quantity of gold, the latter for a reason hereafter adduced being associated with quartz and quartzite pebbles.

The hills through which the Janglu Pani flows are the normal grey and greyish-white Tipam sandstones of Mallet. At their base is a series of blue clays, occasionally highly carbonaceous, to the comparatively rapid erosion of which the basin already mentioned is due.

The source of the Janglu Pani gold was of course one of the main objects of enquiry, the scope of which was soon limited by the discovery of the almost invariable association of the gold with quartz and quartzite pebbles. On washing it was found that these pebbles were sparsely scattered in many places throughout the soil and sub-soil of the hill slopes, and further, that they were invariably associated with gold differing neither in quantity nor in quality from that found in the stream bed. This then is the proximate source of the gold. The more remote source appeared to be the thin layers of gravel intercalated with the Tipam sandstones. Probably there also occur beds of conglomerate, such as a lucky slip revealed to Captain Dalton in 1853, but these were not discovered by the present writer. Sufficient evidence of their presence is, however, afforded by the large pebbles in the stream, and perhaps by the boulders at the Hathi Pung. These last are of granite and gneiss and range up to two feet in diameter. They are unfortunately embedded just at the junction of the rock and sub-soil, and from the evidence furnished it is impossible to say whether they are erratics in the sandstone, or whether they have descended from a stratum further up the hill slope. A trial of the gravel bands, rarely more than an inch in thickness, gave a "prospect" in the dish—small indeed, but sufficient to prove that these gravel beds are competent to supply the gold found in the water-courses. The amount recovered in the dish indicated a content of much less than ¼ grain per ton. It is possible also that some of the gold has been derived from Mallet's Dihing conglomerates, the beds next higher in the section to the Tipam sandstones, and it is equally possible that the degradation of a recent river terrace may have furnished some gold, but no trace could be found in the section either of such older or of more recent conglomerates.

To sum up with regard to the Janglu Pani, the amount of stream gravel available is insignificant, and the gold content is equally so, and is extremely difficult to save. The same remarks apply to the thin gravel beds *in situ*. It is therefore somewhat difficult to believe that the gold yield can ever have been extensive, or that it was indeed

ever more than two or three ounces per annum, and that this supposition is correct is borne out by Captain Hannay's statement in 1838 that the sonwals considered that the time for washing was only after a rise in the river, when a fresh deposit would naturally be formed. That it was ever considered sufficiently rich to work must have been due to the great appreciation of gold in Assam. The slight concentration of gold at this point is due merely to the accident of the stream forcing its way through the low hills, thus forming a natural sluice, and is not due to the erosion or denudation of any rich deposit in the vicinity.

The Brahmaputra above Sadiya.

After the examination of the Janglu Pani the auriferous deposits of the Brahmaputra above Sadiya claimed attention. These had not been unimportant during the *regime* of the Assam Rajas, and an examination of these gravels promised to throw some light on the source of the contained gold. The Noa Dihing, which breaks away from the Buri Dihing in a manner peculiar to the Upper Assam streams on reaching the plains, was not visited. Its gold had, even by the sonwals, been considered too fine to be saved by ordinary means, and proof of this had been obtained by the writer in the washings about Bisa on the Kherim Pani, only 10 miles from the Noa Dihing and where the gold must be of the same derivation as that of the Noa Dihing. A further incentive to examine these deposits lay in the fact that it was in them that the occurrence of the rare metals—platinum, osmium, and iridium—had been determined. In face, however, of the extreme fineness of the gold, and the consequent inability to save it by modern dredging machinery, and of the probable poverty of the deposit, joined to the fact that the rainy season promised to set in early, it was considered inadvisable to spend any time in the examination of that river.

Instead of ascending the Brahmaputra to Digaru Mukh, where canoes must be abandoned for elephants or for coolies, the route selected was by way of the Tenga Pani, a minor stream which for 25 miles flows parallel and at an average distance of five miles from the great river. For the first eight to ten miles of its course, it is a deep rapid stream showing little or no gravel. Above Latau gravel banks occur more and more frequently until Chonkam is reached. From Latau to Chonkam the gravels show gold, but in very small quantities,

generally far less than ½ grain gold per ton. It does not appear that the Tertiary rocks already mentioned as occurring at the Tenga Mukh have any enriching effect on the gravels, a fact that may point to the absence of the conglomerates of the Tipam sandstones from this section. Above Chonkam no appreciable increase in the value of the gravels was noted.

From Chonkam the narrow strip of intervening land was crossed to the main river which was reached at a point opposite the Digaru Mukh. Here the gravel banks gave a few, but far from encouraging "colours." Above the Digaru Mukh the Brahmaputra flows by five main channels through a wide plain. All the branches are running full during the rains, but during the cold weather the waters are confined to two or three channels, the others then showing dry stony beds, devoid, as a rule, of gravel. The route taken up the river was by the most southerly of these channels, at that time dry and forming the road for the pilgrims to the Brahmakhund. No likely spots were seen on this channel. At Parghaut or Mishmi Ghaut the river, whose waters are again united in one stream, changes its course from the east and flows from the south-east along the base of the hills. Here the current has a considerable velocity, generally far too great to admit of the deposition of gravel or of gold, though in sheltered positions small beaches were found. These yielded gold all the way to the Brahmakhund, but in very small quantities and differing nowise in character from that obtained lower down the river. A little gold was found at the Brahmakhund and in the reach above the gorge, which was as far as could be penetrated by way of the river, the Tain Mishmi hill-track to the Miju Mishmi country, towards the head waters of the Brahmaputra, leaving the river at Mishmi Ghaut and lying considerably to the north.

Opposite Mishmi Ghaut, where the pilgrim track up the dry *suti* meets the river, is the old river terrace already described. Owing to the time available for its examination being limited by the necessity for carrying all supplies in this inhospitable and almost uninhabited country, nothing further than a most cursory examination of these old gravels was possible. So far as the examination went—and it was restricted to a number of dish prospects—it failed to reveal the presence of gold. It is possible that an extended examination may show gold in a higher or lower stratum than that examined, but it is far from probable that it exists there in any quantity.

The return journey was made along the opposite or northern bank. The tributaries from this side, of which the Dora and Digaru are the principal, all yielded colours near the Brahmaputra, but failed to show anything in the dish as the hills were approached, where the larger boulders indicated the greater strength of the current during the rains. In the main river it was not until some miles below Digaru Mukh that the river bed, taken as a whole, showed gravels in which there was a reasonable hope of obtaining gold evenly distributed. The spot that appeared most favourable was the Guri Mara, a chapori or island opposite the frontier guard station of Chunpara. Above here, except in the *sutis*, or smaller branches of the river, the current was far too strong to permit of the deposition of the finer grained gravels with which the flour gold of the Brahmaputra is associated. At the Guri Mara is a high gravel bank into which the river is cutting, only to redeposit the material, with the heavier portions perhaps somewhat concentrated, on a half-mile long beach on the same side of the river. Lack of coolies and unwillingness to submit to the long delay, possibly one of weeks duration, necessary to secure these, led to nothing more than dish trials being made here. These showed only 2-3 grains per ton from the beach, and much less from the gravel bank further up the river. Captain Dalton, however, washing here in 1855 in spots pointed out to him by the native sonwals, who had not then entirely abandoned their occupation, obtained from a trial of some sixteen tons a result of nearly 10 grains per ton. It must, however, be remembered that this result, on Captain Dalton's own showing, can by no means be considered an average, for he speaks of the good wash being very limited in quantity. Indeed, most of it had been exhausted before his arrival, and we know how few must have been the number of washers practising their calling in 1855. The economic importance of the features presented at the Guri Mara will be treated later. Below the Guri Mara, gravel banks become rare and are finally replaced entirely by sand.

The Dibong River was examined only above Bomjor, and the best prospects obtained were from 14 miles higher up the stream, nearly opposite the old Nizamghat fort, and about a mile below the mouth of the gorge. This prospect showed, for Assam, fairly coarse gold, but was worth not more than 2 grains per ton. It is possible that this gold is derived from the tertiary sandstones which, as we have already seen, fringe the hills in this place. A gravel bank some

two miles below the gorge and 25-30 feet in height was tried, but without result.

From Sadiya the great Dihong River, the largest of all the affluents of the Brahmaputra, was explored. Gravel first occurs about two miles from its mouth, increasing in quantity as the river is ascended. Gold in small quantities was found everywhere in the gravels until just below the Abor village of Pasighat, where for the first time in Assam a considerable residue of black sand failed to yield colours of gold. Working down the river it was found that it was only after the Dihong separates into two branches, the Lali and the Dihong, that the current had slackened sufficiently to permit of the deposition of gold. The Sibia Mukh appeared to be the most favourable spot for gold on this river, but no banks suitable for dredging were observed in the vicinity and dish "prospects" gave little encouragement to further prospecting. It is probable that much of the gold found about Sibia Mukh has been brought by the Sesseri.

The Subansiri River.

The Subansiri is the last important tributary of the Brahmaputra. So far as is known it drains an immense area of the Eastern Himalayas, but unlike the Dihong, does not break through the Tibetan tableland on the north. It has always been considered by the native washers to be one of the best rivers in Assam for their purpose, and the art of washing has lingered here longer than in any other place. Operations during the past fifty years have been confined to the area in the plains lying immediately at the foot of the ranges, but prior to that time the sonwals were accustomed to proceed to the Sedang, a large tributary of the Subansiri lying well within the hills. There the industry declined and finally ceased owing to the exactions of the hill Miris, in whose country the Sedang is situated, their demands for salt, cloths, and rice exceeding the value of the gold won. The sonwals now living on the Subansiri are of opinion that for every tola of gold to be found in that river, four may be obtained from the Sedang, an estimate probably the normal result of unattainable gold upon the imagination.

The Subansiri, owing to the recent subsidence of the valley noted in another place, does not carry its boulders nearly so far out into the plains as do the other tributaries of the main river, and the area in which gold may be found is thus restricted to only some

six miles below the gorge, little gravel appearing below the Pathalipam tea garden. Even within this area it is only in suitable spots that gold may be found. These spots are the beaches left on the convex curve of a stream bank, and the bars at the lower end of a long pool.

In order to test the value of the gravel flats on either side of the river with a view to "pond dredging," the only form possible during the rains, the banks of the Derpai pool were carefully examined. These were some ten feet in height. The results obtained from dish prospects showed a very small gold content, but the matter was one of such importance that it was considered necessary to supplement the dish prospects by trials in bulk. Two lots of ten tons each were therefore washed for the insignificant yield of 2 and 1½ grains of gold, respectively, representing in either case only 1/5th grain per ton, thus completely confirming the previous trials by dish. The gold obtained was in a state of extremely fine division.

After the failure of the gravel flats, there remained only the beaches and bars of the actual river bed. The majority of these failed to give promising results, but one, at the foot of the pool and on the right bank, formerly much frequented by native washers, was pointed out by Mr. J. L. Alexander, to whom the writer is also indebted for much local information.

Here a trial was made, interrupted at times and finally terminated by floods in the river, which, owing to the abnormally wet season, was far above its usual level at that time of the year. The beach examined was often submerged, and at the lowest level experienced during the course of the trials no more than 50 square yards of the beach were uncovered. As much of this as remained above water level was collected and was at once carried above flood level. The large boulders were separated, and the remainder screened through ½ inch mesh sieves. It was found by actual measurement that the large stones, more than 3-4 inches longest diameter, constituted 54 per cent.: stones between ½ inch and 3 inches, 26 per cent.: and sand less than ½ inch, 20 per cent. of the whole. Of the large stones none were more than 18 inches longest diameter and few would reach that size. None are therefore beyond the capacity of a bucket dredge of moderate size, though stones of the largest size might cause a little delay. Of the sand nearly all will go through a much finer screen, not more than 10-15 per cent. of it being retained on a No. 6 screen. It was found

by trial that 1 cubic foot of this sand weighed 93 lbs., and that therefore 1 cubic yard is roughly 1⅛ tons.

Seven and a half cubic yards of this sand were washed for a return of 7½ dwts. of gold, a return, it need hardly be said, far superior to that obtained from any other part of Assam during the present season. Estimating from careful pan-tests, the heap should have yielded 10 dwts., or at the rate of 28 grains per cubic yard. The difference between the estimated and actual yield arises from the loss of gold by the machines used, and this loss occurred, not in finely divided gold, but in broad flakes thin as gold leaf, which were buoyed up by the water and carried off. On a dredge all such gold would be caught by the judicious use of mercury.

The economic aspects of this deposit will be dealt with later, for the remarks applied to it will generally apply to all the auriferous deposits of Assam of possible economic value.

Of the source of the Subansiri gold nothing very definite can be said. It is in the main certainly not derived from the old high level gravels which fringe the hills to heights of 100-150 feet, for these yielded nothing to the dish. Several of the conglomerate bands of the Sub-Himalayan sandstones were also examined, and though the great majority of the dishes gave no return, two or three showed small colours, sufficient at least to indicate these pebble bands as being the most probable source of the gold. The distribution of the gold lends some support to the assumption. It is, as we have seen, found in the Sedang, the course of which lies almost certainly entirely in the sandstones. That the gold came from the older rocks which lie in the ranges north of the sandstone is negatived by the fact that nearly all the streams flowing from the first range—the Kakoi, Kuddum, and others[1]—and therefore lying wholly within the tertiary rocks, are more or less auriferous.

The Desoi River.

This river was reached late in April when the flood waters had risen so high that examination was impossible. From information

[1] The Duluni or Dulung now yields no gold, but prior to 1845 it was a favourite stream of the gold-washers. A few years before that time a huge flood had brought down immense quantities of sand and had completely buried the payable gravels (Jour. As. Soc. Beng., Vol. XIV, p. 251). Much the same thing has happened in recent years in the Kakoi stream.

gathered from Mr. J. Begg, of Holunguri, and from the surviving native washers, the richest auriferous locality is the Gota Jan, a small branch of the Desoi, some eight miles within the hills, and near the junction of the Tipam sandstone and the coal measures in this place. There the conditions of concentration appear to be very similar to those noted in the Janglu Pani. The gold must also be very finely divided, for the washers expressed great astonishment on being shown the alluvial gold from the Subansiri, saying that they had never such large natural grains. The washers knew of no other auriferous streams in the vicinity, and in the Desoi itself washing was carried on only on suitable gravel banks between the Gota Jan and the Moriani Bridge, a distance of 12 miles. At no time do the washings here appear to have been either rich or numerous. As on the Subansiri, the duruni is, or rather was, the only form of machine used by the sonwals.

From the presence of the Tipam sandstones and of quartz pebbles, the latter being looked upon as an extremely favourable indication, the gold here, as elsewhere in Assam, is probably derived from the coarser pebble layers of that rock series.

Characteristics of Assam Gold.

Except in a few places on the Subansiri, the individual gold grains are extremely small and are invariably much flattened. The largest grains met with, of an extreme length of ⅛ inch, had a thickness of no more than 1/100 inch. In spite of the assertions of the old chroniclers, the gold is not of poor quality, as the following assays show. The evil reputation of Assam gold was due probably to adulteration, if any reliance may be placed in the descriptions of the Assamese character by Mussulman historians.

Samples forwarded to the Calcutta Mint by Captains Dalton and Hannay assayed as follows (Nos. 1, 2, 3),[1] and may be compared with assays (Nos. 4, 5, 6) made by the present writer:—

No.	Locality.	Gold.	Silver.	Base.
1	Brahmaputra River . . .	88·281	...	...
2	Noa Dihing „ . . .	93·880	...	...
3	Dihong „ . . .	90·588	...	...
4	Subansiri „ . . .	89·850	9·240	0·91
5	Ditto „ . . .	89·320	9·680	1·00
6	Janglu Pani „ . . .	92·950	5·580	1·47

[1] Memoirs, Geol. Surv. India, Vol. I, p. 93.

General.

Perhaps the most striking feature presented during the examination of the auriferous deposits of this valley is the universal distribution of the gold in extremely small percentages throughout the gravels of the river beds. This wide distribution is held to be due to two main causes—to the wandering of the Brahmaputra over the plain, and to the wide distribution of the Tipam or Sub-Himalayan sandstones, for these last are certainly auriferous in places.

Since it would appear that these sandstones were deposited by a river system not greatly dissimilar in direction from that at present in existence, it may be conjectured that their contained gold has been derived from the same source as that gold which is now being brought through the Brahmakhund with every flood, *viz.*, the quartz veins of the metamorphic and gneissic schists of the Miju Ranges. It is true that, where seen, these schists contained no well-defined quartz veins, but quartz veins will in all probability be better developed in the immediate neighbourhood of the intrusive igneous rocks, the débris of which is seen strewn in the stream beds.

From the presence of gold higher up the Assam valley than the entrance into it of the Dihong, and from the complete absence of all references to gold washings along the Tibetan Tsanpo, it is extremely improbable that the Tibetan plateau has furnished any of the gold of the Assam valley.

The next characteristic feature to be noted is the general aggregation of the gold at a point, the distance of which from the hills is dependent on the strength of the current and on the form of the gold dust. Above this point the only deposition is that which arises from local diminutions in the velocity of the current, as on the beaches at the end of a long pool, or on the beaches lying parallel with the stream and to which the gold is carried by the back-eddies, where it is retained in the interstices between the large boulders. This point of general deposition is marked on the Assam rivers by the occurrence of gravels containing pebbles up to 6 inches in diameter. Below this point are the fine-grained homogeneous river sands which contain no gold. From the foregoing it therefore follows that :—(*a*) the general search for gold must be confined to those portions of the rivers containing boulders and gravels, and (*b*) particular search must be made at the bars at the end of long pools

especially where a high bank is being eroded, and also in the longitudinal boulder beaches.

To turn now to the economic consideration of the only deposits considered by the writer to be worthy of further prospecting. These spots are the Guri Mara, above Sadiya and opposite the Chunpara stockade; the Sibia Mukh on the Dihong River; and the Derpai pool of the Subansiri River. From causes already indicated, the gravels on the first two were not examined closely, but it requires no greater expenditure than that of Rs. 100—150 to determine in each case whether the deposit is valueless or whether it is sufficiently rich and extensive to justify a further expenditure of some Rs. 2,000—4,000 in determining its value as a dredging proposition. Special attention should be directed to any gravel banks in the vicinity, in the hope that these should prove sufficiently rich to enable dredging work to be carried on during the rains, with a consequent increase of profit during the cold weather when the dredge is working on the presumably richer beaches of the stream beds.

The most promising deposit is, however, that on the Subansiri. Its advantages may be tabulated as follows:—

(1) The portion exposed contains a payable proportion of gold.
(2) The nature of the gravels offers no serious hindrance to successful dredging.
(3) On a properly designed dredge there should be very little loss in gold.

On the other hand, the adverse points are:—

(1) Dredging can only be carried on for four and a half months in the year.
(2) The extent and depth of the deposit are unknown.
(3) While it is certain that a fresh supply of gold is brought to the bars and beaches every year, it is by no means so certain that, after being dredged for one season, the replenishment of the succeeding rainy season will bring the value up to that of the preceding year.

Before this can be considered to contain the elements of a successful dredging proposition, these adverse factors must be provided for or eliminated. The first is due to the fact that, in spite of all trials, it seems quite clear that the alluvial flats on either side of the river do not contain sufficient values to justify dredging, which must therefore be confined during the cold weather to the river beds. The earliest

possible month in which dredging might be commenced is October, and with good fortune, the river may remain sufficiently low until the end of April, but no more than the above-mentioned lapse of time may be safely assumed.

The second point to be settled is the lateral extent and the depth of the auriferous deposit on the Derpai bar. Should it extend far below the water, and should the gold be evenly distributed throughout a considerable depth of gravel, the proposition must certainly be considered eminently payable. This crucial examination presents no great difficulty and would indeed have been performed by the writer during the present season, had it not been for the abnormally early rains, the consequent river floods, and the impossibility of procuring before the close of the season the necessary apparatus for the purpose, all joined to the fact that, since these auriferous deposits are now occupying the attention of private persons, the work is one that may reasonably be left to private enterprise.

The deposits lying in the bed of the river, examination by shafts is out of the question. The use of drilling machinery of the ordinary Keystone type is prohibited by the presence of the large boulders already noted. To the writer, the best and most efficacious method would appear to lie in the use of a hand-power double chain grab, of the Priestman type, and of a capacity of 3-4 cubic feet, and made as watertight as possible. The grab should first be set to work on the bar above water-level, and the depth of the gravel proved at that place, the gravels being transferred to suitable screening and washing machines to determine the values at successive depths. For proving the lateral extent of the deposit beneath the water-level, the derrick should be placed on a pontoon made on the spot from country boats. Skilfully handled, the grab should even under water make a fairly vertical shaft in the gravels. From the pontoon the gravel should be carried to washing machines on the bank and its gold content there ascertained. The actual cost of such prospecting should be no more than Rs. 2,500—3,000, and this initial prospecting is absolutely imperative before any dredging machine capable of dealing with large quantities of gravel is placed on the river. To form a company with a large capital, and to expend money on a dredge before these preliminary details are settled, is merely courting disaster, and from a commercial point of view—the only one which can be taken with regard to these enterprises—is absolutely inexcusable. For success in gold

dredging, unlike in most other forms of gold mining, is not a matter of happy chance, but results from the careful calculation of bulk, value, and expenses—factors which are procurable with comparative ease and cheapness.

Further, as already pointed out, there is a possibility of decrease in value of the bars reformed after dredging. This is a matter which nothing short of actual trial can settle, but it is at the same time one of considerable importance, since the number of dredgable bars is extremely limited, and none examined by the writer approached in any degree the richness of that at the foot of the Derpai pool.

From the foregoing it follows that even if, on further trial, all the conditions appear to be favourable, a company with a limited capital —certainly not more than a lakh of rupees (or say £6,500)—will command the most chances of success, or rather, what is not quite the same thing, the fewest chances of failure. Overcapitalization and the erection of huge plant to deal with unknown conditions will in this, as in any other form of commercial experiment, inevitably spell failure.

The gold on a properly designed dredge should be easily saved. Efficient screening, the size of the smallest mesh being regulated by the maximum breadth of the gold grains,—in the case of the Derpai gold, the largest grains being $\frac{1}{8}$ inch broad, a No. 6 screen—is the first essential. The load of sand on the washing tables is thus reduced to the minimum. Sufficient breadth must be given to the tables to admit of a thin even flow of pulp, so thin that every gold grain may be enabled to come in contact with the canvas or burlap or whatever is used on the tables. Plush, owing to the large percentage of garnet and heavy black sand, will probably be found to choke very easily. To enable the finer leaf gold to be saved, it will be advisable to supplement the canvas tables with amalgamated copper plates.

Despite the above, and despite the fact that owing to the great extent of country covered the majority of the auriferous deposits received no more than the most superficial examination, and many must have been entirely overlooked, the general impression left on the writer's mind as to the potential value of the Assam gold deposits is distinctly unfavourable. Here, as in most other parts of India, the climatic conditions that make for concentration of gold have always been absent. There has never been that even flow of waters confined within well-marked banks, that, continued throughout centuries, finally results in a general separation and a local concentration

according to specific gravity of the river-borne minerals in "leads" and "runs." On the other hand, there have been annual floods, varying so quickly in height, velocity, and direction, that the slight local concentration of one year has been inevitably neutralised during the floods of the succeeding rainy season.

Judging from the great difficulty experienced in locating the exact spots on the various rivers where the richest gold was obtained in former days, it would appear that no good purpose has been served by prohibiting the surviving sonwals from washing. It has indeed been a matter of great hardship to these men, who knew but the one craft, and who, for long, until they finally decided to devote themselves entirely to the less attractive tillage of the soil, were on the verge of starvation. The surviving sonwals—there are but three—expressed the greatest desire to resume work, not so much now for their own sake, as to teach the younger men the art, and to provide them with an additional means of livelihood. They state that nothing but the direct prohibition on the Subansiri and the fear of a heavy royalty on the Desoi have prevented them from working. On the Subansiri they were prohibited in the interests of larger enterprises, but this 35 years of indirect encouragement to capital has been productive of no useful result. Indeed, in those very interests it is most desirable that the younger sonwals should be induced to practise their ancestral calling, thus ensuring a knowledge of the richest gravel banks—a knowledge that we do not now possess.

Moreover, whatever may be true of the river bars below water-level, it is certainly true that the gold of the beaches formerly frequented by the sonwals was renewed from year to year. Even on an ordinary concession their few cubic yards and their few tolas of gold could make but little difference in the gross yield of a dredge, one single revolution of whose buckets will raise more gravel than 15 sonwals can wash in a day.

ON A CURIOUS OCCURRENCE OF SCAPOLITE FROM THE MADRAS PRESIDENCY, *by* E. VREDENBURG, A.R.C.S., *Deputy Superintendent, Geological Survey of India.* (With Plate 29.)

The specimen of which an illustration is herewith published belongs to the Madras Museum, where it is now exhibited. It was sent to the Geological Survey of India by Mr. Edgar Thurston, Superintendent of the Government Museum, Madras, for determination of the curious star-like aggregates of lath-shaped white crystals that occupy one of its faces.

The specimen is said to have been obtained from "a trap dyke in the Godavari district." It is a large, irregular, naturally-weathered block, weighing 66 lbs., with no signs of artificial fracture. It consists mainly of a fine-grained, regular-textured, holocrystalline, basic rock, of specific gravity 3·10, made up of augite, hornblende, and felspar. The augite forms brown translucent grains nearly colourless in a microscopic section. The hornblende grains are black, and, in section, appear dark-brown and strongly pleochroic. The white felspar is a basic plagioclase. The structure is thoroughly granular, without any tendency to development of distinct crystalline shapes.

One face of the large block is flat or slightly concave and is covered with a black film, in the midst of which are the star-like clusters of white crystals shown in the illustration.[1] This black film is scarcely five millimetres thick, and the white, lath-shaped crystals are still thinner, although measuring as much as a centimetre in width. The black mineral of the film is the same hornblende as that of the main rock with which it is in continuity. The mineral forming the broad prismatic crystals is scapolite, showing a striated structure parallel to the direction of the vertical axis. But this mineral does not constitute the entire substance of the white prisms, for the scapolite is surrounded by a very thin shell of basic felspar.

[1] In the illustration, the black portion of the film looks as if suffused with white specks. The large prisms are, however, the only white portions of that particular surface, and the appearance of small white patches is due to the irregular reflection of light upon the cleavage planes of the black hornblende grains.

In the absence of any definite information regarding the mode of occurrence of the rock, there remains some doubt as to the true nature of the film: it may represent the contact between two rock masses of different composition, or it may be a narrow vein filling a fissure through the homogeneous felspar-pyroxene-amphibole rock. Considering the identity of the hornblende of the film with that of the main mass of the rock, the latter explanation appears to be the more probable. The film would then be a contemporaneous vein, that is, a fissure filled-in, before the complete cooling of the rock, by the residual magma, and of about the same bulk composition as the rock itself, for, although the ferro-magnesian and the lime-alumina silicates are distributed differently in the film and in the main mass, their relative amounts cannot much differ in either instance. As scapolite chemically differs from plagioclase mainly in the introduction of chlorine, the alteration in mineralogical composition is presumably due to the action of chlorine vapours passing along the fissure during the cooling of the rock-mass.

MISCELLANEOUS NOTES.

A new form of blue Amphibole from Central India.

An extremely interesting rock, found by Mr. Howard J. Winch, was brought to the Geological Survey Office by Mr. H. Kilburn Scott. The rock, which was found near the deposit of manganese ore at Meghnagar on the Godhra-Ratlam Railway, is of a blue colour with a lavender tinge, and to the naked eye is a schist composed of prisms of blue amphibole, averaging a quarter of an inch long, with an interstitial black mineral. This black mineral is a manganese oxide, while the amphibole is also slightly manganiferous, but in the latter case the manganese reaction obtained may be partly due to a little of the black oxide, which the amphibole usually contains, not having been completely separated, though it was attempted to remove it entirely by the use of Sonstadt's solution. This amphibole also gives a strong flame-reaction for sodium.

Microscopically the rock is seen to be composed of the amphibole with its characteristic prism-angles and interstitial quartz, calcite and a large amount of the black manganese mineral included in all the other three. As the amphibole often shows black cloudings in its interior, probably of secondary origin, besides the original black mineral, it is in all likelihood a manganese amphibole. Its scheme of pleochroism is:—

$\mathfrak{a}$ = pinkish lilac.
$\mathfrak{b}$ = paler lilac.
$\mathfrak{c}$ = blue.

By polarized light it is seen that the mineral shows irregular zoning, due probably to varying composition. As the inner zone seems to have the presumed manganese-ore dust developed in it more readily than the outer shell, it seems probable that there is a gradual change from the most basic composition inside to the most acid outside. This change in composition is accompanied by a change in position of the elasticity axes. For the basic portions of the amphibole the elasticity axis $\mathfrak{a}$ is the one nearest to the vertical crystallographic axis, c'. The angle $\mathfrak{a} \wedge c'$ may be as low as 16°, but as one passes from the interior, most basic, portion to the outer, most acid, portion in a zoned individual, the axis $\mathfrak{a}$ gradually swings away from the vertical crystallographic axis c' till it makes an angle sometimes as large as 70° with c'. The elasticity axis $\mathfrak{c}$ has of course now rotated into proximity

with the crystallographic axis c', making with it an angle of 20°; so that $\mathfrak{c} \wedge c' = 20°$.

As will be seen from the pleochroism scheme, this rotation of the elasticity axes is accompanied by a change from lilac to blue, as the elasticity axis nearest the vertical crystallographic axis changes from $\mathfrak{a}$ to $\mathfrak{c}$; consequently these compound crystals do not show even colouring, but are in irregular patches of blue and lilac. Though some of the crystals in the microscope slide are almost entirely of one composition, either acid or basic, it is easy to distinguish them at once by the colour corresponding to the elasticity axis nearest c', thus :—

Chemical character.	Axis nearest c', is	Corresponding colour.
Basic		Pinkish lilac.
Acid		Blue

The polarization colours of this amphibole are very low, rarely rising above the first order. The sign and other optical properties cannot be determined until some better material has been obtained.

The specific gravity of the rock determined from the mean of two small pieces, is 2·88, while that of a small crystal of amphibole was 2·86, though this latter will necessarily vary with the varying composition of the mineral, as well as with the amount of the black manganese mineral included.

Of the known amphiboles, the one under discussion approaches most nearly, as regards its pleochroism scheme, to the soda-amphibole glaucophane; but even from this it is decidedly different, for the $\mathfrak{a}$ axis colour of glaucophane is given as yellowish green to colourless instead of pinkish lilac. The present mineral differs completely, however, from the soda-amphiboles in having a much smaller specific gravity. Also the angle $\mathfrak{a} \wedge c'$, instead of being 4°—6° as in glaucophane or riebeckite, or 14° as for arfvedsonite, or the 18°—20° of crocidolite, can vary between 16° and 70°. Considering that no other amphiboles are known showing anything like the pleochroism of the present mineral, it is almost certain that we have here a new species of amphibole, characterised by great variation in composition, producing corresponding variations in its optical properties, and it is hoped that an early opportunity will occur for collecting material sufficient for a more complete investigation of the properties of the mineral.

[L. L. FERMOR.]

An unusual occurrence of Common Salt.

The manganese-ore at Kándri mine near Rámtek, in the Nágpúr district of the Central Provinces, is characterized by extremely well developed slickensiding, which separates the ore into huge striated columns dipping to the E. 25° S. at 25°—30°. In level No. 1 a good section across the ore body and country rock has been exposed, and the north-east wall of the deposit is seen to be a fine-grained, greyish and pinkish, schistose, felspathic and micaceous quartzite, which is seen microscopically to contain, besides the quartz, a fair quantity of microcline and white mica with a little magnetite. This rock partakes of the same slickensiding as the manganese-ore, and in common with the latter is divided by joint-planes at right angles to the slickensiding, producing the above-mentioned columns. The cross-joint planes of these quartzite columns were marked in places with black dendrites, doubtless of oxide of manganese, and in other parts had a white saline coating up to a quarter of an inch thick, really composed of fine white needles. Some of this white substance was scraped off, tested in the laboratory, and found to be essentially sodium chloride. As extraneous matter had been included with the salt, Rám Chandran, M.A., separated off 40·3 per cent. of material insoluble in hot water, and found that the solution contained, besides the sodium chloride, also a little calcium, magnesium, and a trace of potassium, with a little sulphuric acid, of course, as sulphate.

Hence, the fine white felt is almost entirely sodium chloride, introduced presumably by percolation of meteoric water, and subsequent concentration by evaporation.

[L. L. FERMOR.]

Assays of Coal and Coke from the Jherria and Rániganj fields.

The following assays of coal and coke from the Jherria and Rániganj fields have been made on samples selected under the superintendence of Mr. E. P. Martin and Professor H. Louis, and are now published, with the consent of the coal companies concerned, through the courtesy of the Right Honourable Sir E. Cassel, for whom the assays have been made. All the coal samples have been uniformly sampled across the working face of the seams, and they consequently are not open to the usual objection made against samples which are picked from a pile, or from a particular part of a seam.

The beds in which the coal is now being mined in the Jherria field were long ago correlated by the Geological Survey with the Barákar series of the

Raniganj coal-field (Hughes, *Mem. Geol. Surv. Ind.*, V., p. 231, 1866), and it is interesting to notice that the low percentage of moisture, noticed by Dr. W. Saise in the coal of the Barákar series in the Rániganj field (vide *Records Geol. Surv. Ind.*, vol. XXXI, p. 104), is characteristic also of the Barákar coal in the Jherria field. In the case of the Barákar coal from the Rániganj field the moisture amounted on an average to 1·00 per cent., whilst in the case of these Jherria coals the average for moisture is 0·90 per cent.

[T. H. HOLLAND.]

COALS FROM THE JHERRIA FIELD.

Seam.	COLLIERY.	Fixed Carbon.	Volatile Matter.	S.	Ash.	Moisture.	Lbs. of water evaporated by 1 lb. coal.	REMARKS.
		%	%	%	%	%		
17	Jamadhoba and Jorapukhar.	59·76	26·54	0·53	11·77	1·40	12·91	Contains 0·098 per cent. phosphorus.
15	Bhaga (coal) . .	62·87	24·71	0·37	11·05	1·00	13·10	
15	Do. (band) . .	53·97	26·42	0·36	18·35	0·90	11·71	
15	Loyabad . . .	60·92	21·90	0·56	15·70	0·92	13·26	Contains 0·197 per cent. phosphorus.
15	Kankanee . .	67·82	21·02	...	10·38	0·78	...	
15	Katras . . .	68·69	19·99	...	10·71	0·61	...	
14	Kankanee . .	71·54	17·28	...	10·52	0·66	...	
14	Jogta . . .	68·51	19·04	0·53	10·92	1·00	13·61	
14	Do. . . .	69·75	19·79	...	10·05	0·41	...	
14	Katras . . .	55·80	20·01	0·56	22·57	1·06	12·27	Contains 0·146 per cent. phosphorus.
13	Alkoosa . . .	61·62	21·23	0·62	15·57	0·96	12·87	Contains 0·258 per cent. phosphorus.
13	Katras . . .	63·75	18·78	0·55	15·72	1·20	12·60	
12	Do. . . .	55·93	22·02	0·63	20·50	0·92	12·47	
12	Alkoosa (band) . .	58·79	19·86	0·62	19·85	0·88	12·71	
12	Do. (coal) . .	62·28	21·65	0·73	14·20	1·14	13·16	
11	Do. . . .	57·39	19·56	0·62	21·75	0·68	11·96	
A	Bhowra . . .	65·99	26·22	...	7·01	0·78	...	

COALS FROM THE RÁNIGANJ FIELD.

Seam.	Colliery.	Fixed Carbon.	Volatile Hydro-carbons.	S.	Ash.	Moisture.	Lbs. of water evaporated by 1 lb. coal.
		%	%	%	%	%	
Gourangdi .	Gourangdi . .	51·76	26·99	0·68	19·45	1·12	12·51
Deshergarh .	Panchgachia . .	51·01	31·32	0·67	14·70	2·30	12·52
Do. .	Sanctoria and Sodepur.	52·80	33·60	0·30	11·70	1·60	13·36
Sanctoria .	Sanctoria . .	53·68	33·80	0·25	10·55	1·72	13·16

COKES MADE FROM JHERRIA COAL.

No. of Coal-Seam.	Colliery.	C.	S.	P.	Ash.	Moisture.
		%	%	%	%	%
15	Loyabad . . .	73·91	0·50	0·23	23·91	1·45
15	Do. . . .	76·48	0·53	0·29	21·58	1·12
15	Kankanee . . .	79·67	0·73	0·17	18·98	0·45
15	Katras	77·03	0·60	0·09	31·99	0·29
14	Kankanee . . .	76·97	0·77	0·20	22·00	0·06
14	Katras . . .	71·02	0·67	0·32	27·76	0·23
13	Do. . . .	76·30	0·62	0·06	22·80	0·28
13	Do. . .	64·22	0·65	0·03	34·97	0·13
A	Bhowra . . .	80·91	0·85	0·14	17·79	0·31

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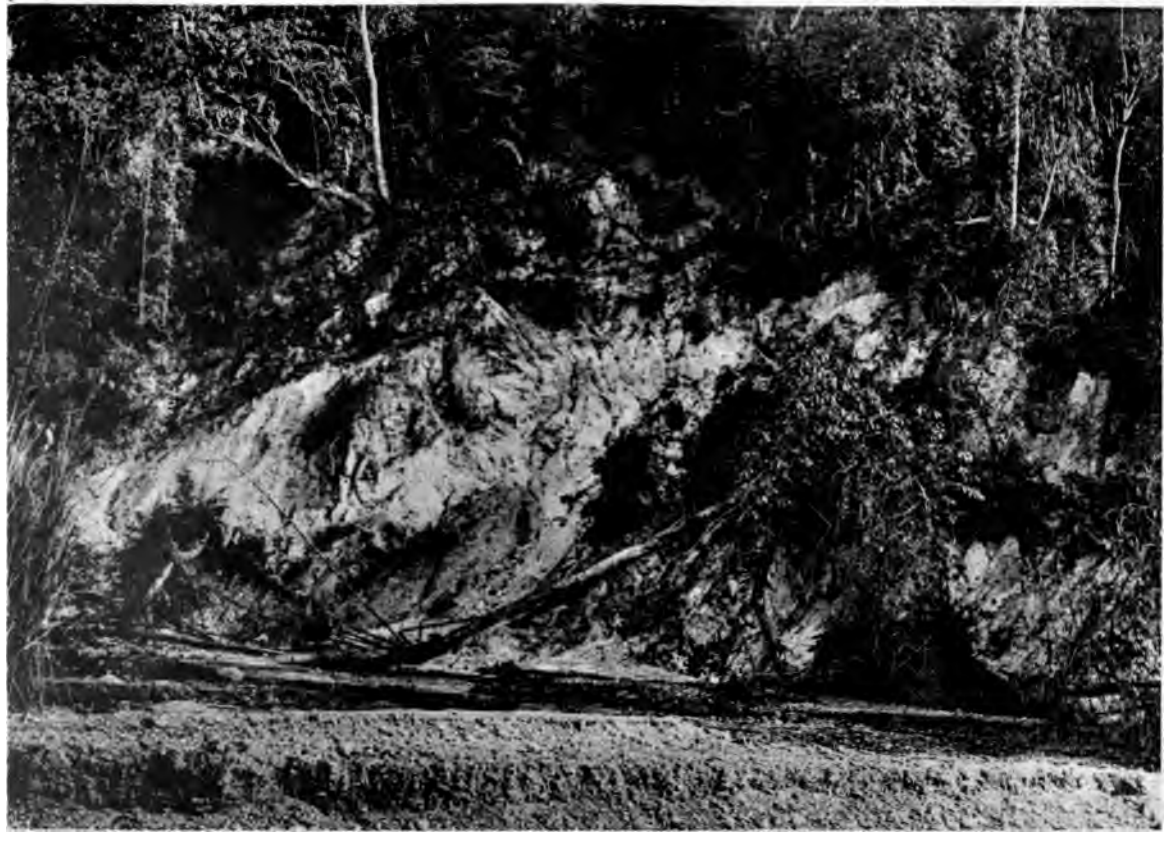

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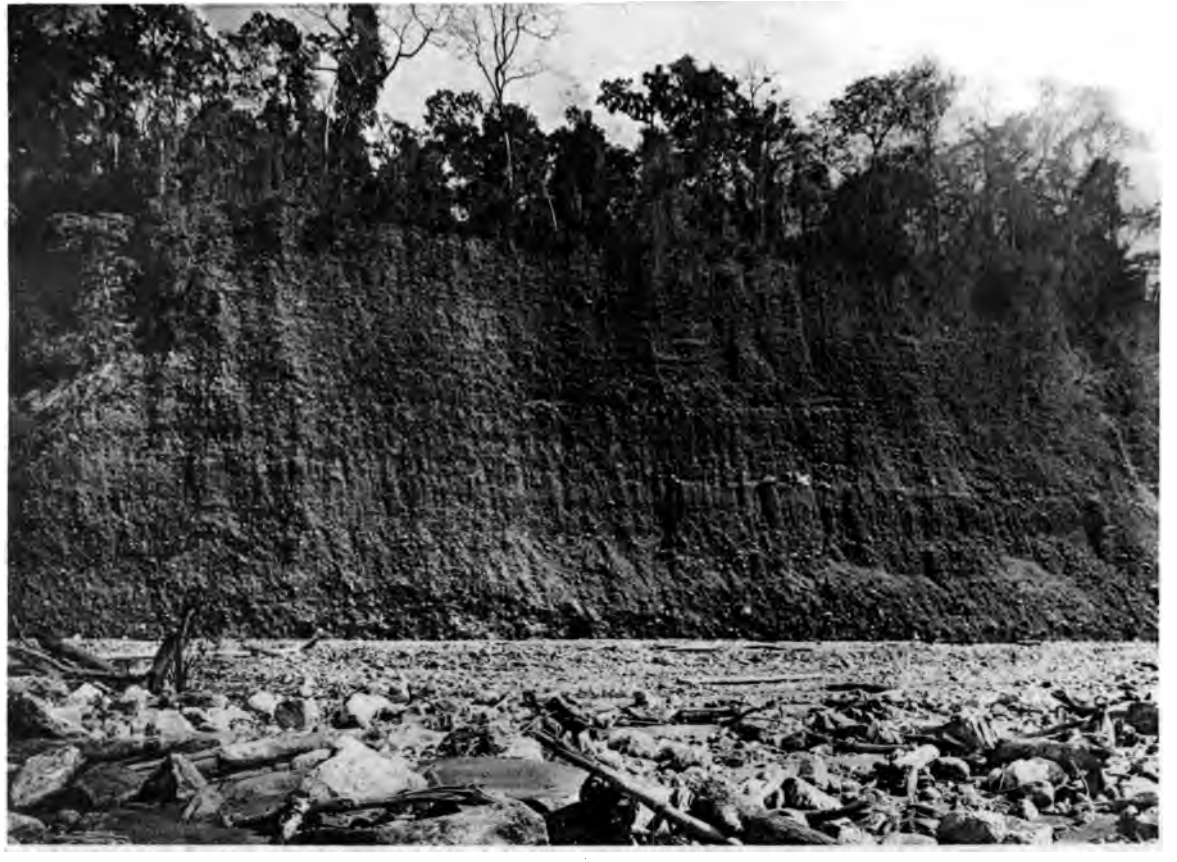

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HIGH-LEVEL GRAVEL, MISHMI GHAT, ASSAM.

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SUBANSIRI GORGE, ASSAM.

J. Lindsay Alexander Esq., Photo. (Fig. 1.)

NATIVE WASHER AND ASSISTANT.

J. M. Maclaren, Photo. (Fig. 2.) *Bemrose, Collo., Derby, Eng.*

DURUNIS AND NATIVE WASHERS, ASSAM.

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AURIFEROUS GRAVEL, JANGLU PANI.

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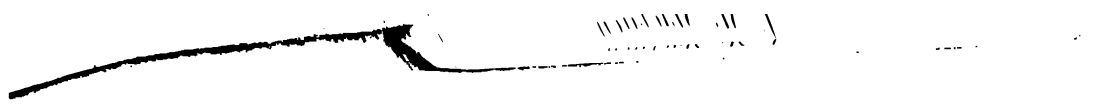

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FROM THE GORGE OF THE SUBANSIRI, SHOWING THE GRAVEL BEACHES.

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FROM THE GORGE OF THE SUBANSIRI, SHOWING THE GRAVEL BEACHES.

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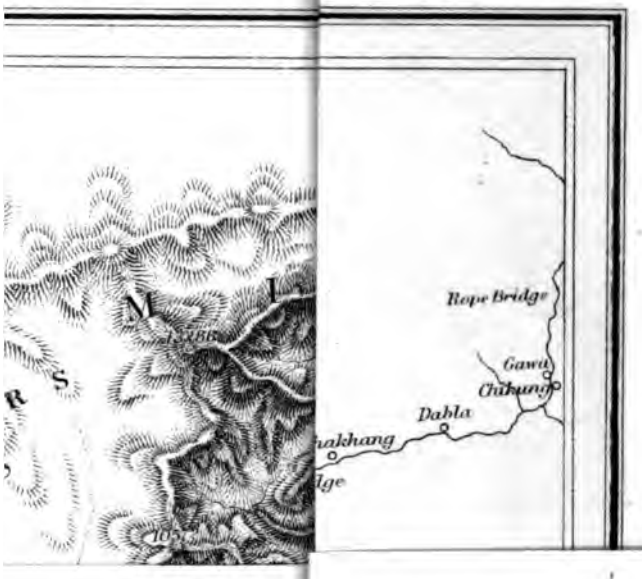
AURIFEROUS BEACH, DERPAI POOL.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BASIC ROCK WITH LARGE CRYSTALS OF SCAPOLITE.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME XXXI.

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J. M. Maclaren, Photo. *Bemrose, Collo., Derby, Eng.*

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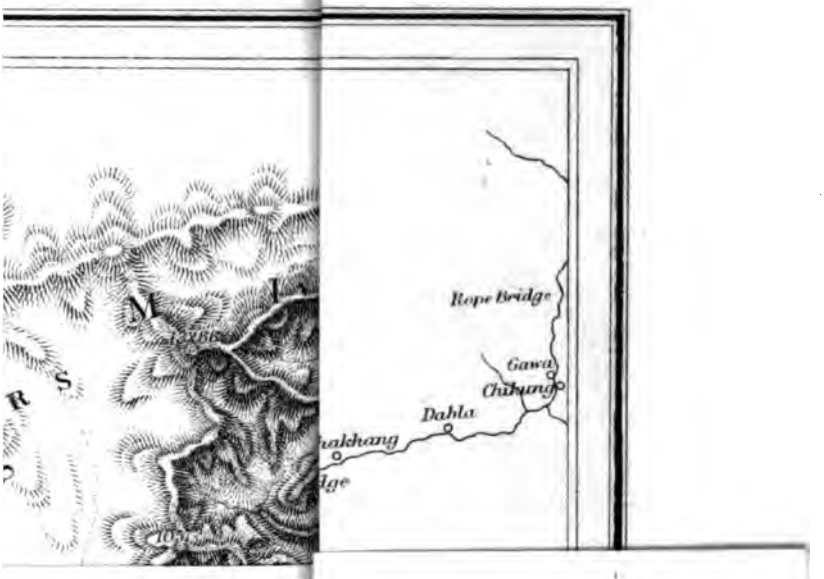
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Part 3.—The Upper Palæozoic formations of Burma. Note on the Chronology and History of the Sind Valley. On the occurrence of a Species of Halarctos in the Trias of Baluchistan. Notes on the Geology and Mineral Resources of Shayurkhani. Miscellaneous Notes.

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Part 1.—Annual report for 1873. On the geological structure of the hill ranges between the Indus valley in Ladak and Shahidula on the frontier of Yarkand territory. On some of the iron ores of European. On the raw materials for iron-smelting in the Raniganj field. On the habitat in India of the so-called sandstone, or so-called Hæmatite. Geological notes on part of Northern Hazaribagh.

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Part 4.—The auriferous rocks of the Dharwar hills, Dharwar district. Remarks on certain considerations adduced by Falconer in support of the antiquity of the human race in India. Geological notes made on a visit to the coal recently discovered in the country of the Luni Pathans, south-east corner of Afghanistan. Note on the progress of geological investigation in the Godavari district, Madras Presidency. Notes upon the auxiliary materials for artificial fuel.

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Part 2. (out of print).—On the gold-fields of south-east Wynaad, Madras Presidency. Geological notes on the Khairsun hills in the Upper Punjab. On water-bearing strata of the Sirsa district. Sketch of the geology of Scindia's territories.

Part 3.—The Shahpur coal-field, with notice of coal explorations in the Narbada region. Note on coal recently found near Mosboog, Khasia Hills.

Part 4.—Note on the geology of Nepal. The Baigarh and Hingi coal-fields.

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Part 1 (out of print).—Annual report for 1875. On the geology of Sind.

Part 2.—The retirement of Dr. Oldham. On the age of some fossil floras in India. Description of a cranium of Stegodon Ganesa, with notes on the subgenus And allied forms. Note upon the Sub-Himalayan series in the Jaina (Jowinsar) Hills.

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Part 4.—On the age of some fossil floras in India. On the osteology of Merycopotamus dissimilis. Addenda and Corrigenda to paper on tertiary mammalia. Occurrence of Pteronotus in India. On the geology of the Pir Panjal and neighbouring districts.

Vol. X, 1877.

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Part 2.—On the rocks of the Lower Godavari. On the 'Argali-Sandstones' near Cuttack. On fossil floras in India. Notices of new or rare mammals from the Siwaliks. On the Aravali series in North-western Rajputana. Borings for coal in India. On the geology of India.

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Part 4.—On the Geology of the Mahanadi basin and its vicinity. On the diamonds, gold, and lead ores of the Sambalpur district. Note on 'Reyna Comp. Batrevensis.' M. Coy. from the Sripermatur group near Madras. On fossil floras in India. The Blaini group and the 'Central Gneiss' in the Simla Himalayas. Remarks on some statements in Mr. Wynne's paper on the tertiaries of the North-west Punjab. Note on the genera Choetomerys and Rhagatherium.

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Part 1.—Annual report for 1877. On the geology of the Upper Godavari basin, between the river Wardha and the Godavari, near the civil station of Sironcha. On the geology of Kashmir, Kishtwar, and Pangi. Notices of Siwalik mammals. The palæontological relations of the Gondwana system. On 'Eozoon' &c., by Mr. Theobald upon erratics in the Punjab.'

Part 2.—On the Geology of Sind (second notice). On the origin of the Kumaun lakes. On a trip over the Milam Pass, Kumaon. The wood volcanoes of Barren and Chedubu. On the mineral resources of Barren, Cheduba, and the adjacent islands.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1905. [January.

REVIEW OF THE MINERAL PRODUCTION OF INDIA DURING THE YEARS 1898 TO 1903.

BY T. H. HOLLAND, F.R.S., *Director, Geological Survey of India.* (With Plates 1—6.)

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I.—INTRODUCTION.

Origin of the Review.

FOR the four years 1894 to 1897, a Review of the Mineral Production of India was issued annually by the Reporter on Economic Products; but in 1898 it was decided, owing to the want of uniformity in the rate of development of many minerals, to publish reviews of progress at wider intervals, covering periods sufficiently long to permit the determination of any decided secular variations in the mineral industry. The present Review, covering the period of six years, 1898 to 1903, is the first essay in this direction; but, in accordance with the orders of Government, five-year periods will be adopted for the future, and the Quinquennial Review of Mineral Production will be published in the Records of the Geological Survey of India.

In this review the minerals are grouped according to the system laid down by Government ten years ago, namely—

Group I.—Those for which approximately trustworthy returns are available; and

Group II.—Those regarding which definitely recurring particulars cannot be procured.

Grouping of the minerals.

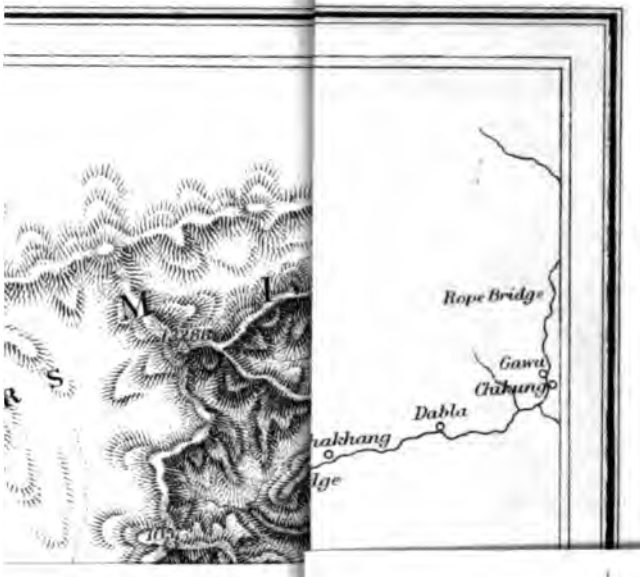
In the first review, issued by Sir George Watt in 1894, the minerals referable to Group I included only Salt, Coal, Iron-ore, and Petroleum, and in the three subsequent issues of the same publication no advance was shown in transferring minerals from Group II to Group I. It is possible now, however, to raise several minerals to the level of those for which approximately trustworthy returns are available, and the minerals thus included in this group are:—

Coal.	Mica.
Gold.	Petroleum.
Graphite.	Rubies.
Iron-ore.	Salt.
Jadeite.	Saltpetre.
Magnesite.	Tin.
Manganese-ore.	

In the case of Gold, the most precise and elaborate details are obtainable for more than 99 per cent. of the production, and approximate values are obtainable for the rest. For Graphite, accurate returns of quantity are obtained from the only company engaged in regular mining for the mineral. Although the returns sent in for the production of Jadeite and Mica are manifestly understated, both minerals are worked largely for export, and, as far as value is concerned, the export figures may be accepted as an approximate estimate of the trade in each case, whilst the nature of the error being known, the figures are not liable to be misleading. Manganese-ore has come into prominence since the older reviews were issued, and may now be transferred to Group I, as the mineral is worked entirely for export, and the totals obtained from returns made by the District Officers agree very closely with those obtained from the ports. Rubies admit of the remarks applicable to Gold: the amount recovered other than by the Burma Ruby Mines Company may be neglected as an unimportant fraction of the total. Saltpetre and Tin are, with less certainty, entitled to places in this group. For Saltpetre, the returns for production are evidently understated, being less each year than the quantity exported, but the export figures may be taken as only slightly less than those for the production of refined Saltpetre. The returns for Tin refer to two districts only in South Burma, but the estimates are probably more reliable than those for Iron, which was originally included in Group I.

Missing minerals.

This Review is directed primarily to a survey of the progress already made, and for anything approaching an idea of the material awaiting development the reader must consult the Manual of Economic Geology, now in course of revision by the Geological Survey Department. But besides the substances whose existence has been determined by the exploratory work to which a geological survey is properly restricted with regard to minerals of economic value, the attention of prospectors might be directed to the minerals which have lately come into prominence through recent industrial developments, and which, in a country including the geological variety of India, are at present conspicuous by an absence that is probably only the result of absence of search. Amongst these are some minerals of the so-called rare metals, which, being generally of high specific gravity, should be searched for in the heavy concentrates of river gravels (see p. 114).


Rope Bridge
Gawu
Chabung
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II.—SUMMARY OF PROGRESS.

Total values.

THE following table summarizes the values of the principal minerals produced during the six years under review. The totals have the obvious defect of being due to the addition of unlike denominations; for export values, being the only returns obtainable in some cases, are ranged with spot values, while the latter necessarily vary with the position of the mine, representing not the *values*, but the *prices* obtainable. In the case of coal, for instance, the so-called value of a ton of good coal in Bengal is less than half that of the inferior material raised in Baluchistan or Burma; in the case of salt, the values given are the prices charged, and these, on an average, are but one-tenth of the duty, which is the principal value of the salt to Government; certain valuable mineral products, like building-stone, are omitted altogether for want of even approximate estimates.

The values returned for minerals exported are also necessarily lower than they would be if the minerals were consumed in the country, and it is consequently unfair to compare this table of values with corresponding returns for countries in which metallurgical industries flourish. Manganese-ore is a conspicuous example of a product which, according to its quality, may be worth 30 to 40 shillings a ton to the European steel-maker, but which is of less value to the Indian producer by the heavy cost of transport. The country is thus not only so much poorer by the loss of the metal exported in the ore, but is paid in return little more than half its market value.

The imperfections of the table are those confessedly inseparable from all such estimates of mineral production; and it is of use merely as a means of comparing one year with another, the same system being carried through the whole period under review. It will be seen that there has been, year by year, a steady, uninterrupted progress in production, from a total of £3,455,565 in 1898, to £4,988,527 in 1903—an increase of 44·37 per cent. in five years. To this total increase every mineral has contributed, except jadeite and amber, and for both of these

figures are of more doubtful value than for most of the other rals.

LE 1.—*Total Value of Minerals for which Returns of Production are available for the years 1898 to 1903.*

Minerals.	1898.	1899.	1900.	1901.	1902.	1903.	*Average.*
	£	£	£	£	£	£	£
. . .	1,608,504	1,724,906	1,891,767	1,930,411	1,970,230	2,302,493	*1,904,719*
(a) . . .	957,162	1,063,820	1,343,081	1,323,372	1,366,909	1,299,716	*1,225,677*
b) . .	358,933	312,682	325,970	409,019	344,633	336,147	*347,897*
tre (c) . .	265,896	232,896	256,210	294,249	237,880	288,487	*262,603*
eum (a) .	67,897	125,684	148,755	200,342	217,816	354,365	*185,810*
s . .	57,950	90,848	97,326	104,476	86,895	98,575	*89,345*
(c) . . .	53,890	73,372	109,554	70,034	87,594	86,277	*80,120*
anese-ore .	27,426	39,529	77,304	79,119	120,538	132,741	*79,443*
one (c) . .	41,780	42,120	58,955	46,377	31,713	47,676	*44,770*
re (e) . .	12,403	12,836	11,171	13,598	16,533	14,963	*13,584*
ite (d) . .	110	7,620	9,145	13,635	24,410	16,970	*11,981*
. . .	2,553	7,900	8,534	7,773	5,340	9,153	*6,875*
esite (d) . .	...	56	150	...	2,360	550	*519*
r . . .	1,061	151	103	11	432	414	*362*
TOTAL .	3,455,565	3,734,420	4,338,025	4,492,416	4,513,283	4,988,527	*4,253,705*

(a) Spot prices. (c) Export values.
(b) Prices without duty. (d) Estimated values.
(e) Estimated values for provinces other than Bengal.

eral character of inerals worked.

)n looking over the returns for mineral production in India for the past six years, two features stand out most conspicuously. Firstly, there has been a remarkable progress in developing the few minerals which :onsumed by what conveniently might be called direct processes,

such as Coal, Gold, Petroleum, Gem-stones, and Salt, or which are raised for simple export, such as Manganese-ore, Graphite, Saltpetre, Mica, and Tin. Secondly, there has been an equally remarkable neglect of the metalliferous ores and the minerals which are necessary to the more complicated chemical and metallurgical industries.

The neglect of metalliferous ores.

The principal reason for the neglect of metalliferous minerals is the fact that in modern metallurgical and chemical developments the bye-product has come to be a serious and indispensable item in the sources of profit, and the failure to utilize the bye-products necessarily involves neglect of the minerals which will not pay to work for the metal alone. Copper sulphide ores are conspicuous examples of the kind: many of the most profitable copper mines in the World could not be worked but for the demand for sulphur in sulphuric acid manufacture, and for sulphuric acid there would be no demand but for a string of other chemical industries in which it is used (*cf.* page 117). A country like India must be content, therefore, to pay the tax of imports until industries arise demanding a sufficient number of chemical products to complete an economic cycle, for chemical and metallurgical industries are essentially gregarious in their habits.

Value of mineral imports.

An examination of our import statistics shows how far the domestic production falls short of the requirements of the country in minerals and mineral products. During the three years 1901-1903 the average annual value of these imports was £10,158,252, and this figure does not include the value of glassware, earthenware, porcelain, machinery, railway material, hardware, and the innumerable articles which, though made from metals known to exist in India, have values greatly in excess of the raw materials used in their manufacture, and which, in any case, would be partly made elsewhere. Of the average annual total, 54·7 per cent., or £5,559,511, was paid for metals alone.

Summary for the Minerals of Group I.

Coal.

In the case of Coal, the Indian output has risen from a little over 4 million tons in 1897 to 7½ million tons in 1903, and within the period under review, India, for the first, though probably also for the only, time, secured the leading place as a coal-producer amongst British dependencies. Of the total output, the Bengal coal-mines contributed the chief, and an annually increasing,

fraction, from 78·6 per cent. in 1898 to 85·5 per cent. of the total in 1903. On account of the fact that very little development has occurred in metallurgical industries, the coal consumption of India is not likely greatly to exceed that of Australia, and will certainly fall behind that of Canada, until our metalliferous ores, and especially those of iron, are raised for smelting in the country.

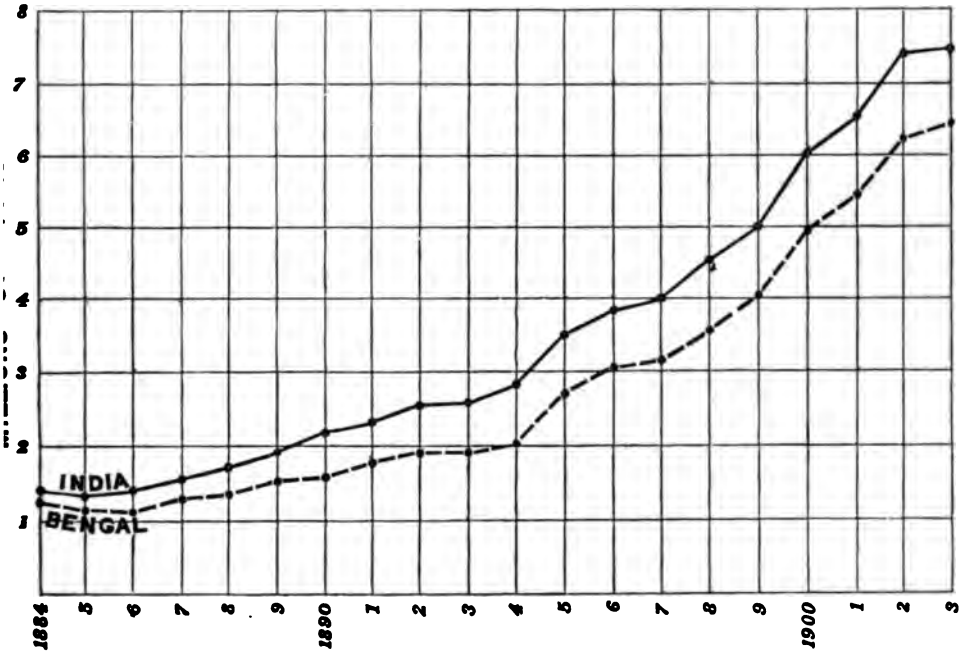

FIG. 1.—*Production of Coal for 20 years.*

As far as they go in their small way, it is satisfactory, from the coal-miners' point of view, to observe that, within the period under review, the figures for imports and exports have become reversed, with every sign of permanency in their present relative positions (figure 2, page 10).

Another feature of the coal trade—which is satisfactory also to those with wider interests than the coal-miner—is the fact that whilst the railways have reduced their purchases of foreign coal to the dimensions of mere samples—as shown graphically in figure 3 (page 11)—and whilst their total coal bill has been steadily increasing, they have

been, at the same time, taking year by year a gradually shrinking fraction of the total output of the mines—a fact which indicates that other coal-consuming, industrial enterprises have developed at a greater rate than railway expansion.

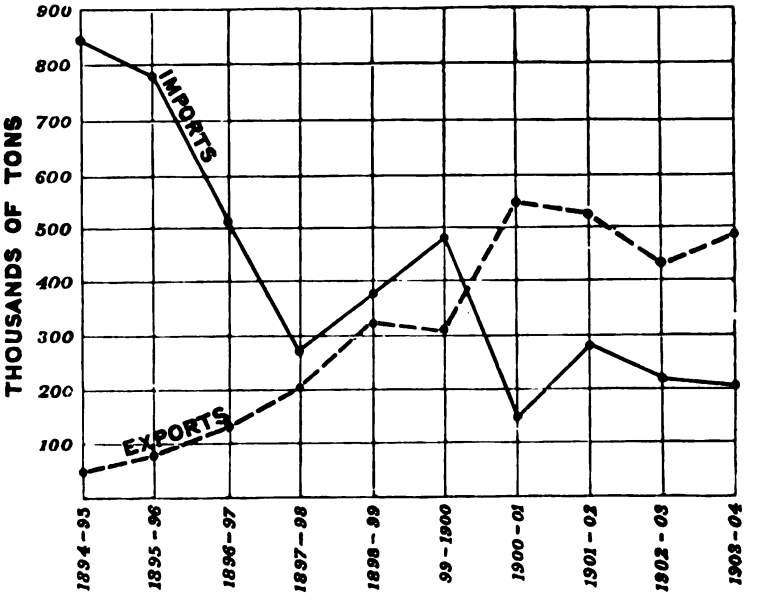

FIG. 2.—*Exports and Imports of Coal for the past 10 years.*

Gold.

The production of Gold has shown a steady increase, from a total of 390,595 ounces, valued at £1,568,065, in 1897, to 603,218 ounces, valued at £2,302,492, in 1903. The progress since 1890 is shown in figure 4 (page 12).

By far the largest fraction of the output has been obtained from a single reef in the Kolar field, Mysore State, but promising work in reef-mining has recently been commenced in the Nizam's Dominions and in the Dharwar district, Bombay Presidency, whilst preparations are being made for an extension of dredging operations on the gravels of the Upper Irawadi river in Burma.

Graphite.

Amongst the minerals which have been taken up more seriously during the period under review, the Graphite of Travancore and the Magnesite of Salem in Madras are noticeable. The Graphite raised during the three years

Photographed by E. Vredenburg. *Beaurose, Collo., Derby, Eng.*

BASIC ROCK WITH LARGE CRYSTALS OF SCAPOLITE

Figure 6, showing the fluctuations in total weight and total value of the mica exported, demonstrates in an interesting way the change which took place in the ratio of the two, when, near the beginning of the period under review, the Indian mica-miners began to turn over their waste heaps to supply the demand for the cheaper "flimsy" mica required for the newly-invented micanite.

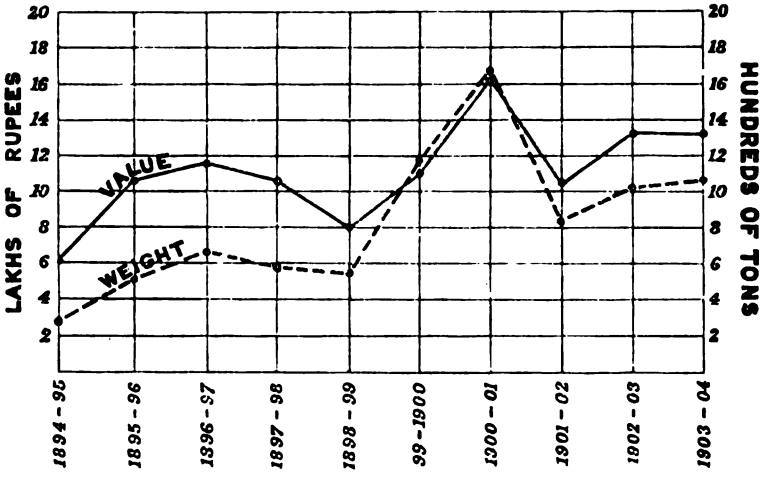

FIG. 6.—*Exports of Indian Mica during the past 10 years.*

Petroleum.

The Petroleum industry has increased at a greater rate even than coal-mining. From a production of just 19 million gallons in 1897, the output rose to nearly 88 million gallons in 1903, and in addition to the export of considerable quantities of paraffin wax, the illuminating oils and petrol refined in Burma and Assam have at last shown signs of definitely displacing foreign supplies in the Indian market (figure 7, page 15).

Rubies.

Next to Petroleum, Rubies now form the chief source of revenue amongst mineral products in Burma, the Ruby-Mining Company under the new lease having entered a favourable phase after a long period of uncertainty in its prospects. The Company paid its first dividend of 5 per cent. in 1898, and continued to work with greater profits in 1899 and the following years.

Salt.

The production of Salt has shown considerable fluctuations, from 1,102,039 tons in 1901 to 823,184 tons in 1903, the average annual production for India, exclusive

Magnesite.

Magnesite-mining was hardly established before the close of 1903, but preparations on a large scale are now being made to open up the well-known deposits near Salem, in which the mineral occurs in a condition of exceptional purity.

Manganese-ore.

The rapid rise of Manganese-ore mining is probably just now the most conspicuous feature in the mineral industry of India. Twelve years ago the industry had not definitely started, whilst last year India turned out a larger quantity of high-grade ores than any country except Russia. The diagram forming figure 5 shows that, within the period under review, work commenced in the Central Provinces, and on account of the high degree of richness and purity of the ore-bodies there opened up, production rapidly developed, in spite of the handicap of a railway journey of 500 to 600 miles between the mines and the coast. The recent discovery of deposits in the Bombay Presidency nearer the coast will probably result in a still further expansion of the export trade, which, however, in view of the unlimited fuel supplies lying idle in India, and the annually increasing bill for imported steel, cannot be regarded with unmixed satisfaction.

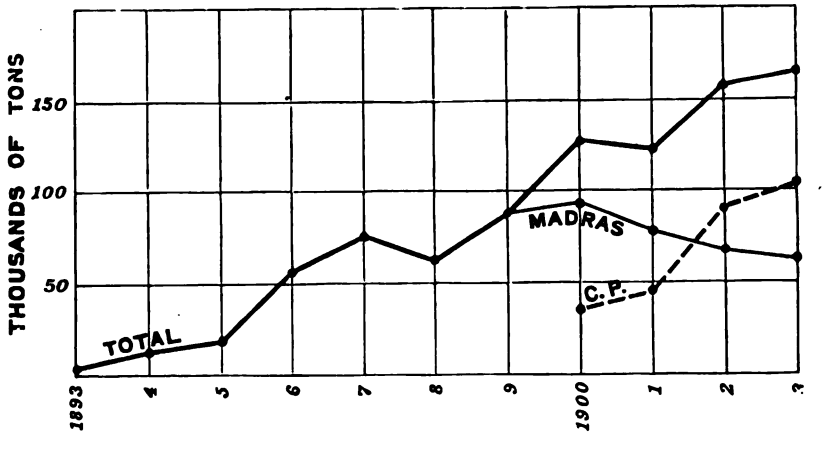

FIG. 5.—*Production of Manganese-ore since the commencement in 1893.*

Mica.

Although India is still the leading producer, and is supplying something like half the World's wants in Mica, the miner in India has not secured a satisfactorily large share of the recently increased trade in this mineral, and the returns for India show a smaller degree of expansion than those for consumption in Europe and America.

of Aden, having been 979,572 tons for the period under review. Of this amount 61·8 per cent. was obtained from sea-water, 27 per cent. was obtained from sub-soil brine and from lakes in areas of internal drainage, whilst the remainder, 11·2 per cent., was raised from the rock-salt deposits in the Punjab and North-West Frontier Province. The average annual import of foreign salt amounted to 433,754 tons, of which 89·8 per cent. was imported to Bengal, and 10·1 per cent. entered Burma.

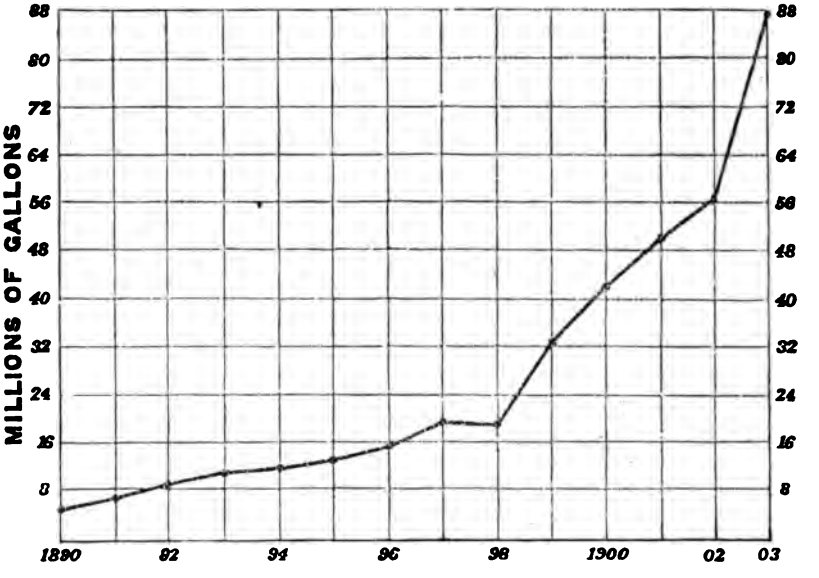

FIG. 7.—*Production of Petroleum since 1890.*

Saltpetre.

The production of Saltpetre is evidently understated, being considerably below the quantities returned as exports. The average annual exports for the six years amounted to 382,353 cwt., of which 30·7 per cent. went to the United Kingdom, 25·7 per cent. to Hong-Kong, and 24·0 per cent. was exported to the United States. Most of the saltpetre was manufactured in Behar, and 98·5 per cent. of the total left India through the port of Calcutta. The only trans-frontier trade of importance is the import of saltpetre from Nepal, the average annual amount for the period under review being 9,417 cwts.

Tin.

Although Tin-mining in South Burma is still practised on a small scale, there has been a marked improvement in the returns, and the persistently high price of tin is likely to inspire more enterprise in the exploitation of these deposits, which are a natural continuation of those in the Malay Peninsula, from which more than half the World's supply is obtained.

III.—DETAILED ACCOUNT OF THE MINERALS OF GROUP I.

Coal.

Progress in output.

DURING the period of six years under review, the output of Coal rose from a total of 4,066,294 tons in 1897 to 7,438,386 tons in 1903, an increase of 83 per cent. (table 2). The expansion was, however, mostly confined to the first five years of this period, as in 1903 the production exceeded that of 1902 by only 13,906 tons.

TABLE 2.—*Production of Coal during the years 1898 to 1903.*

Year.	Quantity.	Total value at the place of production.	*Average value per ton at the mines.*
	Tons.	Rupees.	*Rupees.*
1898	4,608,196	1,43,57,436	*3·12*
1899	5,093,260	1,59,57,301	*3·13*
1900	6,118,692	2,01,46,222	*3·29*
1901	6,635,727	1,98,50,582	*2·99*
1902	7,424,480	2,05,03,639	*2·76*
1903	7,438,386	1,94,95,741	*2·62*

Prices.

From this table it will be noticed that during the latter half of the period under review supplies began to exceed the demand, and lower prices, on an average, were accepted. The average *prices* paid for coal at the pit's mouth are rather unfairly stated as *values*, but the figures are nevertheless interesting as indications of the rates at which coal can be raised with profit. The average rate given as Rs. 2·76 (3*s.* 8*d.*) in 1902 was much

below that of most coal-producing countries of the same year. The following table shows the declared pit-mouth value in some other countries for 1902 :—

Countries.	Per ton.	Countries.	Per ton.
	s. d.		*s. d.*
United Kingdom . .	8 2¾	Australia . . .	7 9
Germany	8 10¼	New Zealand . . .	10 0
United States . . .	5 8¼	Canada	9 3

Comparison of India with Canada and Australia.

A reference to table 3 will show that in 1902 India, for the first time, secured the leading place as a coal-producer amongst the British dependencies, although the amount of coal raised was only 2·95 per cent. of the total for the British Empire in the same year, and only 0·94 per cent. of the World's total output. The figures are not mere curiosities to those who know the leading conditions affecting production. In 1895 Canada produced more coal than India, but India then began to supply the eastern steamship companies in consequence of the high prices produced by the English colliers' strikes of the two preceding years, and for the first time the returns for 1896 showed that India was leading as coal-producer, but was still well behind Australia. Australia was overtaken in 1902, and India thus enjoyed the first place; but it is unlikely that this position will be occupied for more than the one year, and the returns for 1903, when published, will probably show India giving way, not to Australia, but to Canada. If this prove to be true, the causes will be worth the attention of those interested in Indian coal-mining. Canada for many years was a small producer of iron and steel, and its rich deposits of iron-ore in the region of the Great Lakes, where Canadian territory is without coal deposits, were worked for export to the adjoining States of the American Union. In 1900 the total production of pig-iron in Canada amounted to 86,090 tons and of steel 23,577 tons only; but iron and steel works were started in the chief coal-producing colony, Nova Scotia, at the end of 1901, and the result is a reported production of 319,557 tons of pig-iron and 182,037 tons of steel for 1902. Iron and steel-making, more than most

manufacturing industries, creates a market for coal, and if this industry flourishes in Canada, India will resume its second place as a coal-producer until its resources in iron-ore can, in the same way, be utilized for the consumption of coal. Australia at present is, like India, dependent for most of its iron supplies from outside sources, and, like India, must depend on other industries and on exports for a coal market.

TABLE 3.—*Production of Coal in the three large British Dependencies.*

Countries.	1898.		1899.		1900.		1901.		1902.	
	Metric tons.	Per cent. of British output.	Metric tons.	Per cent. of British output.	Metric tons.	Per cent. of British output.	Metric tons.	Per cent. of British output.	Metric tons.	Per cent. of British output.
Australia .	5,490,776	2·49	5,539,382	2·31	6,479,991	2·61	7,000,227	2·86	6,968,514	2·72
Canada .	3,785,372	1·72	4,142,202	1·73	4,837,291	1·95	5,612,108	2·29	6,930,220	2·71
India .	4,203,199	1·91	5,016,390	2·09	6,216,882	2·51	6,742,214	2·76	7,543,625	2·95
TOTAL for British Empire.	220,301,426		239,995,148		247,938,725		244,463,996		256,003,411	

Relation of consumption to production.

The market for Indian coal must be limited to (1) its own home industries, and (2) the Indian Ocean ports, where the manufacturing industries requiring coal are comparatively few, and where India is not the sole supplier of fuel. Tables 4 and 6 show that during the last six years India consumed on an average 93·1 per cent. of the coal produced in the country, and, in addition, imported annually on an average 298,940 tons of foreign coal, which must have been, in calorific value, very little below the slightly larger quantity of Indian coal sent out of the country during the same period.

The actual annual increment of consumption since 1897 has been, on an average, 509,919 tons a year, whilst the increment of production during the same period has averaged 562,015 tons. As the figures for consumption and production do not differ seriously, the great expansion

which has taken place in the Indian coal trade must have been made possible by industrial developments in India itself. The next few years will show whether this expansion is a correct index to the development of other industries, or whether it is the result mainly of increased facilities of transport and of consequent access to new markets.

TABLE 4.—*Relation of Consumption to Production.*

YEAR.	Total consumption of coal in India.	CONSUMPTION OF INDIAN COAL IN INDIA.(a)	
		Quantity.	*Percentage of Indian production.*
	Tons.	Tons.	
1898 . . .	4,660,154	4,280,929	92·9
1899 . . .	5,269,563	4,788,373	94·1
1900 . . .	5,719,136	5,576,669	91·1
1901 . . .	6,396,466	6,110,680	92·1
1902 . . .	7,221,241	6,992,679	94·2
1903 . . .	7,189,167	6,996,438	94·1
Average .	*6,075,954*	*5,790,961*	*93·1*

(a) The consumption of coal is assumed to be production *plus* imports *minus* exports. In the exports a ton of coke is taken to be equivalent to 1½ tons coal required for its production. The imports include Government stores.

Consumption of coal on Indian railways.

The railways in India have consumed on an average 29·7 per cent. of the coal produced during the past six years and table 5 shows that there has been a slight tendency for the consumption of Indian coal on the railways to form a gradually smaller fraction of the output from the mines. This is probably not merely a temporary effect, as the figures for a corresponding period ten years back, namely, 1888 to 1893, show, when treated in the same way, that the consumption of Indian coal on the railways averaged at that time 32·6 of the production. As the differences between exports and imports have been, on an average, insufficient to affect seriously the figures for total coal consumption,

and as the railways in India now consume a smaller percentage of the output than in former years, the expansion in Indian coal production may be regarded as a partial measure of the expansion of other industrial enterprises. It is not a complete measure of such expansion, as new markets have been found in recent years for Indian coal; and as probably most of the available markets have been entered now, the rate of increase in production in the future will be more nearly limited to the rate of expansion in the industries of the country. For this reason, the future of Indian coal-mining would be brighter if there were a prospect here, as in Canada, of a sensible development of the metallurgical industries; these are the real consumers of coal, and it is only when they are developed in India that the expansion in coal-mining will make a serious inroad into the enormous supplies of coal available in the country.

TABLE 5.—*Coal consumed on Indian Railways during the years 1898 to 1903.*

YEAR.	INDIAN COAL.			FOREIGN COAL.		TOTAL Consumption.
	Quantity.	*Per cent. of Total.*	Per cent. of Indian output.	Quantity.	*Per cent. of Total.*	
	Tons.			Tons.		Tons.
1898 . . .	1,422,103	97·3	30·9	39,004	2·7	1,461,107
1899 . . .	1,557,000	95·0	30·6	82,446	5·0	1,639,446
1900 . . .	1,855,610	97·2	30·3	54,339	2·8	1,909,949
1901 . . .	1,956,601	99·3	29·5	13,248	0·7	1,969,849
1902 . . .	2,091,992	99·0	28·2	21,469	1 0	2,113,461
1903 . . .	2 203,889	99·2	29·6	17,696	0·8	2,221,585
Average .	*1,847,866*	...	29·7	...	...	...

Foreign coal on Indian railways.

The country is now rapidly assuming the position of supplying its whole wants in mineral fuel. Table 6 and figure 2 (page 10) show that the imports of foreign coal for all purposes have been gradually diminishing,

whilst table 5 and figure 3 show that on the railways foreign coal has been almost entirely cut out. Twenty years ago the foreign coal consumed on the railways amounted to 31 per cent. of the total; ten years ago this was reduced to 10·7 per cent., whilst during the past six years the foreign coal has averaged 2·16 per cent. of the supplies to the railways, and during the last three years this has been reduced to under 1 per cent. In other words, twenty years ago foreign coal was a serious item in the fuel supplies of the railways: it is now imported in mere samples.

Imports and exports.

The interchange of positions, which has occurred between exports and imports during the last 20 years, is clearly shown in figure 2, and in more detail on plate 1. The actual reversal has occurred within the period under review, as shown in table 6.

TABLE 6.—*Imports and Exports of Coal during the years 1897-98 to 1902-03, including Government Stores.*(*a*)

YEAR.	Imports.	Exports.
	Tons.	Tons.
1897-98	276,407	213,146
1898-99	379,225	327,267
1899-00	481,190	304,887
1900-01	142,467	542,023
1901-02	285,786	525,047
1902-03	228,562	431,831
Average .	*298,940*	*390,695*

(*a*) The figures include coke and patent fuel, each ton of coke being counted as 1½ tons of coal.

It is important to observe, with regard to both imports and exports, that the reversal of position, although it looks striking when expressed in diagrammatic form, has taken place on comparatively small quantities, both being insignificant beside the production and consumption within India itself.

Imports.

The countries from which foreign coal supplies have been obtained are shown in table 7, from which it will be seen that the principal portion of the supplies has been obtained from Great Britain, and that practically all of the remainder has come from Australia and Japan.

TABLE 7.—*Origin of Imported Coal, Coke, and Patent Fuel.*

YEAR.	United Kingdom.	Australia.	Japan.	Other Countries.	TOTAL.
	Tons.	Tons.	Tons.	Tons.	Tons.
1897-98 . .	245,555	16,406	14,213	233	276,407
1898-99 . .	326,794	18,778	32,281	1,372	379,225
1899-00 . .	375,269	20,282	82,936	2,703	481,190
1900-01 . .	98,315	14,638	27,967	1,547	142,467
1901-02 . .	211,327	19,685	53,440	1,334	285,786
1902-03 . .	210,904	6,237	6,975	4,446	228,562
Average .	*244,694*	*16,005*	*36,302*	*1,939*	*298,940*

Exports.

The distribution of exported Indian coal is shown in table 8, from which it will be seen that Ceylon and the Straits Settlements have taken the principal share, the averages for the six years being 246,352 tons of coal in the case of Ceylon and 85,095 tons in the case of the Straits, the returns for coke being of small importance.

Possible expansion of the export trade.

The variations in exports to the two chief customers are shown graphically on plate 1. Of the causes which led to the decline in the exports to Ceylon during the last three years, one has been reported to be the unfavourable reputation earned by the shipment of inferior coal to meet the increased demands made in 1900. If this is the case, the cure is in the hands of the Bengal coal-owners, for the demand must have been no real strain on the supplies available, and the figures given in table 9 will show that the markets of Ceylon and Singapore are

both large enough to be worth the serious attention of Indian coal-shippers.

TABLE 8.—*Exports of Indian Coal.*

——	1897-98.	1898-99.	1899-00.	1900-01.	1901-02.	1902-03.	*Average.*
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	*Tons.*
Aden . . .	8,094	14,416	4,000	53,305	47,194	21,214	*24,704*
British East Africa .	3,619	150	...	20,569	16,922	11,562	*8,804*
Ceylon . . .	104,524	214,986	180,909	368,031	335,651	274,010	*246,352*
Mauritius . .	7,317	2,708	18,128	5,759	18,745	14,690	*11,224*
Natal . . .	...	287	6,072	598	160	2,324	*1,573*
Straits Settlements .	85,280	93,462	86,951	65,715	89,592	89,567	*85,095*
Sumatra . .	...	...	3,531	10,863	10,690	14,655	*6,623*
Other Places . .	3,439	769	4,392	15,450	5,012	3,032	*5,349*
TOTAL Exports .	212,273	326,778	303,983	540,290	523,966	431,054	389,724
VALUE .	£ 142,283	£ 223,100	£ 217,776	£ 393,889	£ 375,977	£ 257,968	£ 268,499

TABLE 9.—*Foreign Coal Imports of Ceylon and Singapore for the years 1901 to 1903.*(*a*)

ORIGIN OF THE COAL.	CEYLON.			SINGAPORE.		
	1901.	1902.	1903.	1901.	1902.	1903.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
England .	286,842	288,362	246,500	60,419	50,984	52,500
Japan . .	6,300	...	26,400	433,548	370,426	400,000
Australia . .	5,522	3,752	12,200	38,965	36,087	44,500

(*a*) For Indian coal sent to Ceylon and Singapore, see table 8.

Calcutta exports.

Practically all the coal exported leaves by the port of Calcutta, which, being the nearest port to the Bengal coal-fields, is the centre of distribution to the other ports of India. The quantity exported from Calcutta during the past six years is shown in table 10 to have averaged 1,622,686 tons, with the two highest records in 1901 and 1903 and a distinct general increase from the year 1898 onwards.

TABLE 10.—*Coal shipped from Calcutta during the years 1898 to 1903.*

——	1898.	1899.	1900.	1501.	1902.	1903.	*Average.*
To Foreign Ports .	314,562	269,112	488,555	587,100	428,995	438,975	*421,216*
„ Indian Ports .	906,509	867,161	1,245,996	1,407,913	1,267,528	1,513,711	*1,201,470*
TOTAL .	1,221,071	1,136,273	1,734,551	1,995,013	1,696,523	1,952,686	*1,622,686*

Of Indian ports, Bombay is by far the most important market for Bengal coal, having, during the period under report, taken on an average 679,445 tons a year, with a maximum of 881,806 tons in the last year, 1903. The amount of Bengal coal taken at Bombay is now well beyond the foreign imports, which, during the same period, averaged 192,237 tons, by far the largest fraction having come from the United Kingdom.

The distribution of Bengal coal to Indian ports is shown in table 11, on page 26, from which it will be seen that the places of importance after Bombay have been, in order, Rangoon, Madras, Karachi, Cuddalore, and Negapatam.

Production by provinces.

Table 12 (page 27) shows that amongst the provinces Bengal occupies the leading position as a coal-producer, whilst a glance at figure 1 (page 9) will show that the Bengal output is not only the largest part, but has been a yearly increasing fraction of the total, the contribution having risen from 78·6 per cent. in 1898 to 85·5 per cent. in 1903. Three coal-fields in Bengal, namely, Raniganj, Jherria, and Giridih, have yielded nearly all the coal hitherto credited to Bengal, but the Daltonganj field, which is now connected with the East Indian Railway system, has recently been opened up by the Bengal Coal Company.

TABLE 11.—*Distribution of Bengal Coal to Indian Ports.*

PLACES.	1898.	1899.	1900	1901.	1902.	1903.	*Average.*
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	*Tons.*
Akyab . .	1,614	2,167	5,575	6,160	9,745	2,293	*4,592*
Balasore . .	2,681	219	4	...	...	13	*486*
Bassein . .	...	4,622	3,900	7,221	15,112	9,852	(*b*) *8,141*
Bhownagar .	...	...	...	...	...	15,690	(*a*) *15,690*
Bombay . .	449,302	399,121	824,080	861,859	660,504	881,806	*679,445*
Chandbali . .	6,985	1,875	625	465	192	212	*1,726*
Chittagong .	785	2,671	3,791	3,637	2,288	3,374	*2,758*
Cocanada . .	100	...	...	4,226	...	1,000	*888*
Cuddalore . .	22,635	28,706	12,088	31,591	21,492	33,293	*24,968*
Karachi . .	20,801	...	4,730	14,108	84,825	54,824	*29,881*
Kyaukpyu . .	473	514	605	497	181	40	*385*
Madras . .	193,102	193,667	136,189	173,171	150,850	170,760	*169,62*
Mandapam .	...	...	...	...	...	13,974	(*a*) *13,9*
Marmagoa . .	...	...	...	...	...	14,380	(*a*) *14,3*
Moulmein . .	1,359	1,120	2,270	1,338	3,571	1,619	*1,*
Negapatam .	24,226	18,930	28,199	31,009	23,754	21,557	*24*
Pondicherry .	...	6,120	3,994	10,088	7,571	5,000	(*b*) (
Port Blair . .	750	1,000	1,000	750	6,000	6,009	
Rangoon . .	169,979	188,619	209,469	242,777	261,213	264,344	*2*
Teticorin . .	10,677	17,007	9,237	18,285	12,505	12,918	
Other Ports .	1,040	803	240	731	7,725	753	
TOTAL .	906,569	867,161	1,245,996	1,407,913	1,267,528	1,513,711	

(*a*) One year only. | (*b*) Average for 1899 to 1903 only.

TABLE 12.—*Output of Indian Coal by Provinces for the years 1898 to 1903.*

YEAR.	Assam.	Baluchistan.	Bengal.	Burma.	Central India.	Central Provinces.	Hyderabad.	Punjab and Kashmir.	Rajputana.	TOTAL.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1898	200,329	13,372	3,622,090	6,975	134,726	149,709	394,622	85,862	511	4,608,196
1899	225,623	15,822	4,035,265	8,105	164,569	156,576	401,216	81,835	4,249	5,093,260
1900	216,736	23,281	4,978,492	10,228	164,489	172,842	469,291	74,083	9,250	6,118,692
1901	254,100	24,656	5,487,585	12,466	164,362	191,516	421,218	67,730	12,094	6,635,727
1902	221,096	33,889	6,259,236	13,302	171,538	196,581	455,424	56,511	16,503	7,424,480
1903	239,328	46,909	6,361,212	9,306	193,277	159,154	362,733	44,703	21,764	7,438,386

fields, there has also been an increase, though a much smaller one, in all the provinces, except in the Punjab, where the Dandot colliery in the Salt Range, which has been the chief producer, has been gradually failing (*cf.* table 17, page 35).

TABLE 14.—*Output of Gondwana Coalfields for the years 1898 to 1903.*

COALFIELD.	1898.	1899.	1900.	1901.	1902.	1903.
Bengal:—	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Daling	2,191	2,098	1,490	...	...	...
Daltonganj	...	...	707	3,881	19,352	33,557
Giridih	653,047	628,777	712,727	694,806	776,656	766,871
Jherria	749,988	1,007,236	1,710,757	1,946,763	2,420,786	2,493,729
Rajmahal	423	412	397	436	219	335
Raniganj	2,216,441	2,396,742	2,552,414	2,841,699	3,042,223	3,066,720
Central India:—						
Umaria and Johilla	134,726	164,569	164,489	164,362	171,538	193,477
Central Provinces:—						
Mohpani	22,472	23,596	39,612	43,046	43,645	31,443
Pench valley	...	...	...	...	...	88
Warora	127,237	132,980	133,230	148,470	153,336	127,623
Hyderabad:—						
Singareni	394,622	401,216	469,291	421,218	455,424	362,733
TOTAL Gondwana beds	4,301,147	4,757,626	5,785,114	6,264,681	7,083,179	7,076,376

Raniganj and Jherria.

Taking the Gondwana areas first, we find that the Raniganj field, which was the first to be developed, still holds the lead (see table 14), having turned out 41·2 per cent. of the total production for India in 1903. Jherria, further

west in the Damuda valley, is, however, rapidly overtaking Raniganj since its railway connection to the capital by the East Indian line has been supplemented by a branch from the Bengal-Nagpur system. In 1897 Jherria contributed only 8·2 per cent. of the Indian output, whilst in the last year, 1903, the production of this field amounted to 33·5 per cent. of the total.

The coal from the Raniganj field is mainly derived from seams in the highest beds of the Damuda series, the lowest, or Barakar stage, being less developed in the exposures along the northern margin of the field. In the Jherria field the converse is the case: the uppermost stage has yielded poor coal, whilst in the Barakar series there are some eighteen well-defined seams, of which the upper eight seams include enormous supplies of good coal. The two classes of coal present a well-marked and constant difference in the amount of moisture they contain: the older, Barakar, coals, both in the Raniganj field and in Jherria, contain on an average about 1 per cent. of moisture, whilst the average for the younger coal of the Raniganj series is 3·8 per cent. in the lower seams, and nearly 7 per cent in the upper seams. There is a corresponding, but less marked, difference in the proportion of volatile hydrocarbons, which form a larger percentage of the younger coals than of those at lower stages in the Damuda series.

Giridih.

The small patch of coal-bearing Gondwana rocks near Giridih is practically divided between the Bengal Coal and the East Indian Railway Companies. The chief wealth of the field is stored in a 15-foot seam of good steam and coking coal near the base of the Damuda series. This coal has the following average composition:—

Fixed carbon	66·4
Volatile matter	24·4
Ash	9·2

The output of the field, which is controlled largely by the requirements of the railway company, has been rising gradually during the last six years from 660,665 tons in 1897 to 766,871 tons in 1903, and the remaining workable supplies probably do not exceed 77 million tons. A proposal for introducing modern methods of coke-making with a view to the recovery of the valuable bye-products is now being considered by the East Indian Railway Company.[1]

[1] T. H. Ward: Modern methods of coke-making. Rec. Geol. Surv. Ind., vol. XXXI, 92 (1904).

The other principal coal-fields being worked on the Peninsula are, Warora, Mohpani, and those of the Pench valley in the Central Provinces, Umaria in the Rewah State, and Singareni in the Nizam's Dominions.

Pench valley.

In the Pench valley and the belt of related coal-bearing Gondwana rocks dipping under the Satpura range, only prospecting work has been done so far; but favourable results have been obtained by locomotive trials on samples of the coal, and the proximity of the fields to the great manganese-ore deposits, and (when connected by direct rail to Nagpur or Itarsi) to the markets of Bombay and the mills of the Deccan, will give these deposits an opportunity of developing whatever intrinsic merits they possess.

Mohpani.

The coal-bearing rocks which dip under the Upper Gondwanas of the Satpura range re-appear near Mohpani in the Narsinghpur district, where they have just escaped total concealment by the Narbada alluvium. The Mohpani colliery has been worked since 1862 by the Nerbudda Coal and Iron Company, and, through various difficulties, has made very little progress. Between the years 1898 and 1903 the annual output from this colliery rose from 22,472 to 43,645 tons during the first five years, but a drop occurred in 1903, due to the final abandonment of the old mines and the development of work in the newly-discovered area two miles further west.

Warora.

The Warora basin, about 62 miles south of Nagpur, in the Chanda district, has been worked since 1871 by the State. About half the coal raised, which averaged 137,146 tons a year for the years 1898 to 1903, has been taken by the Great Indian Peninsular Railway, the rest going to cotton mills and factories in Nagpur and other parts of the Central Provinces. The coal is liable to spontaneous combustion, and a large part of the field has been lost by fire and walled-off. The Warora colliery has been worked under distinctly greater natural difficulties than those usually met with in Bengal, but an examination of the chief results obtained by the present able management will probably be of value to those interested in Indian coal-mining. Table 15 shows the financial results of the past six years' working of the colliery. These results are shown graphically in relation to coal output on plate 3.

TABLE 15.—*Financial Results of the Warora Colliery during the years 1898 to 1903.*

YEAR.	Gross earnings.	Working expenses.	FINANCIAL RESULT.	
			Net earnings.	*Percentage on Capital.*
	£	£	£	
1898	39,719	28,247	11,472	*9·58*
1899	40,193	27,661	12,532	*10·96*
1900	40,507	26,939	13,568	*12·22*
1901	46,085	28,875	17,210	*15·90*
1902	46,669	29,267	17,402	*17·11*
1903	39,499	26,616	12,883	*13·16*

The average selling price of coal at Warora during the past six years has been Rs. 4-7 a ton, and the average cost of its production during the same period has been Rs. 3-1-5, of which a considerable fraction is due to charges for the sinking fund. This cost has been distributed as follows:—

	Annas
Mine Working Expenses—	
Superintendence	3·24
Coal-cutting	12·85
Underground haulage, including maintenance of shafts, roads and working ways, with repairs . . .	9·87
Surface haulage, including lighting and maintenance of permanent way	1·25
Pumping	7·54
Ventilation	1·65
Staff-quarters and other buildings	0·42
Miscellaneous	1·52
Management and Office Expenses—	
Local Offices, Police, Medical and India Office charges	3·07
Sinking Fund charges	8·01
TOTAL .	49·42 annas.

The returns for labour at Warora, notwithstanding the difficulties arising from water and liability to spontaneous combustion, show that the system of mining adopted permits of a satisfactory output per person employed, whilst the deaths due to accidents have been reduced to

a low rate. During the six years, 1898 to 1903, the average annual output of coal per person employed was 132 tons, whilst there were four deaths only during the period in which 822,876 tons of coal were raised, and the death-rate from mining accidents averaged 0·64 per 1,000 employed. Another three or four years will probably see the end of the Warora colliery, but, with the extension of the Wardha valley line southwards, the extensive deposits near Bellarpur will be opened up.

Singareni.

The great belt of Gondwana rocks, near the north-west end of which Warora is situated, stretches down the Godavari valley as far as Rajamundry, and at one or two places the equivalents of the coal-bearing Damuda series in Bengal are found cropping up from below the Upper Gondwana rocks. One of these occurrences near Yellandu in the Nizam's Dominions forms the coalfield well known by the name of Singareni. The principal seam of coal, some 5 to 6 feet thick, being worked at the Singareni colliery, was discovered by the late Dr. W. King of the Geological Survey in 1872, but mining operations were not commenced until 1886, since when the output has rapidly risen to over 400,000 tons a year, although the production last year, 1903, showed a decline to 362,733 tons, owing to a serious subsidence in one of the workings (see table 14 and plate 2).

Coal-mining at Singareni has been accompanied by a heavier loss of life by accidents than in the general run of Gondwana fields. Table 16 shows the death-rate on this field compared with the rate in Bengal.

TABLE 16.—*Death-rate from Accidents at Singareni compared with Bengal.*

	—	1898.	1899.	1900.	1901.	1902.	1903.	*Average.*
SINGARENI.	Number of persons employed.	6,788	8,450	8,045	7,616	7,538	6,359	*7,473*
	Deaths from accidents .	9	8	9	12	17	29	*14*
	Death-rate per 1,000 employed.	1·33	0·94	1·12	1·58	2·25	4·56	*1·87*
Death-rate in Bengal coal-fields		*0·45*	*0·52*	*0·60*	*0·53*	*0·53*	*0·85*	*0·58*

Umaria.

The Bilaspur-Katni Branch of the Bengal-Nagpur Railway passes through the small coalfield of Umaria in the Rewah State, Central India. The quantity of workable coal in this field is estimated at about 24 million tons, and during the past six years the output has been gradually rising from 134,726 tons in 1898 to 193,277 in 1903 (see table 14, and plate 2). The four coal seams being worked vary from about 3 to 12 feet in thickness, and dip about 4° to the north-east. The mines were opened in 1882 under the direction of Mr. T. W. H. Hughes of the Geological Survey, and were controlled by Government until the 1st January 1900, when they were handed over to the Rewah State. Most of the coal raised is sold to the Indian Midland (Great Indian Peninsular) Railway, and a small quantity to the Bengal Nagpur Railway and other customers.

Cretaceous and Tertiary Coalfields.

The younger coals are nearly all of Cretaceous and Tertiary age, although some thin and poor seams of Upper Jurassic coal have been worked in Cutch. The Cretaceous beds occur in the Khasia and Garo hills in Assam, where they are found in small basins resting on the Archæan schists and gneisses. The Cretaceous coals of Assam are generally distinguished by the inclusion in them of nests of fossil resin, and this character was noticed in the coal recently discovered to the north of Shillong.[1]

Coal of Tertiary age is found in Sind, Rajputana, Baluchistan, along the foot-hills of the Himalayas, further east in Assam, in Burma, and in the Andaman and Nicobar Islands. The most frequent occurrence is in association with nummulitic limestones, though the richest deposits, namely, those in North-East Assam, are younger, probably miocene, in age. Of these Extra-Peninsular fields, the only ones producing coal are of Tertiary age. The output for each of these for the years 1898 to 1903 is shown in table 17 (page 35).

On the whole, the younger coals, which are being worked in Extra-Peninsular areas, differ from the Gondwana coals in containing a larger proportion of moisture and volatile hydrocarbons, and though as variable in composition as they are in thickness of seam, coals are obtained,

[1] P. N. Bose: Report on the Um-Rileng coal-beds, Assam. Rec. Geol. Surv. Ind., XXXI, 35 (1904).

as for instance in Assam, with a remarkably low percentage of ash and having a high calorific value.

TABLE 17.—*Production of Tertiary Coal during the years 1898 to 1903.*

Province and field.	1898.	1899.	1900.	1901.	1902.	1903.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Assam :—						
Makum	202,178	232,933	215,962	254,109	220,640	239,328
Smaller fields . .	1,367	807	774	...	456	...
Baluchistan :—						
Khost	10,662	11,689	17,664	18,431	25,982	36,444
Sor Range and Mach .	5	265	5,617	6,225	7,907	10,485
Burma :—						
Shwebo: Thingadaw .	6,975	8,105	10,228	12,466	13,302	9,306
Kashmir :—						
Ladda	...	...	...	...	1,138	999
Punjab :—						
Dandot . . .	74,590	81,218	74,083	67,730	55,373	43,704
Other mines . . .	11,272	617	...	...	...	...
Rajputana :—						
Bikaner . . .	...	...	9,250	12,094	16,503	21,764
TOTAL for Tertiary beds .	307,049	335,634	333,578	371,046	341,201	362,010

North-East Assam.

The most promising amongst these young coals is the group of occurrences in North-East Assam, one of which is now being worked by the Assam Railways and Trading Company, who commenced operations at Makum (27°15′; 95°45′) in 1881. The collieries are connected by a metre-gauge railway with Dibrugarh on the Brahmaputra river, which, being navigable, forms both a market and a means of transport for the coal. The most valuable seams occur between the Tirap and Namdang streams, where,

for a distance of about five miles, the seams vary from 15 to 75 feet in thickness. The average dip is 40°, but as the outcrops in many places are several hundred feet above the plains, facilities exist for working the coal by adit levels. The average coal production of the Makum mines during the last six years has been 227,523 tons a year. The coal has the reputation of being a good fuel, and forms an excellent coke.

Shwebo district, Burma.

Coal occurs in various parts of Burma, and in the Shwebo district the annual output during the years 1898 to 1903 varied between 6,975 and 13,302 tons without signs of expansion. The only point worth adding to previously published accounts of the Burma coal is the fact that during the past year it has been definitely ascertained that in the Nammaw field, which is some 30 miles from the Mandalay-Lashio Railway line, the existence of seams of good coal, 10 feet thick, has been recently verified by the Geological Survey. This and the Lashio field, further north in the Northern Shan States, are likely to be of importance to the new railway lines in that area.

Baluchistan, Khost.

Possibly the most important of the coal deposits in the west occur in Baluchistan, where, however, the disturbed state of the rocks renders mining operations difficult, expensive, and often dangerous. Besides the small mines being worked in the Sor range, south-east of Quetta, and in the Bolan pass at Mach, collieries have been worked since 1877 at Khost (30° 12′ ; 67°40′) on the Sind-Pishin Railway. The two seams being worked have an average thickness respectively of 26 and 57 inches, and the output has gradually risen from 10,662 tons in 1898 to 36,444 tons in 1903.

To the natural difficulties of the ground is added a serious scarcity of trained labour, and as a consequence the working results of these mines appear to be unfavourable when compared with the exceptional conditions existing on the Gondwana fields of Peninsular India. Table 18 (on page 37) shows the financial results of the undertaking, which is under the control of the North Western State Railway.

The output per person employed at Khost has averaged only 44 tons per annum during the past six years, and the difficulties of the work are further shown by the fact that the death-rate from mining accidents has been, in the same period, 23·2 per thousand persons employed ; but of this serious loss of life, 47 out of a total of 64 deaths were caused on October 12th, 1899, by a fire in the Takrai mine. Besides

the stratigraphical difficulties arising from working the Tertiary coal seams, which are often irregular in thickness and lie in disturbed, uncertain ground, there are additional dangers due to the liability of most of these pyritous coals to spontaneous combustion, and to the danger of explosions by the large quantities of dust generally formed in working such friable coals.

TABLE 18.—*Summary of the Financial Results of Working the Khost Colliery during the years 1898 to 1903.*

YEAR.	Gross earnings.	Working expenses.	FINANCIAL RESULT.	
			Net earnings.	*Percentage on capital.*
	£	£	£	
1898	9,423	8,371	1,052	*25·00*
1899	10,482	11,334	−852	...
1900	16,290	14,443	1,847	*19·11*
1901	14,500	11,379	3,121	*22·77*
1902	18,509	17,266	1,243	*7·01*
1903	23,804	19,978	3,826	*17·02*

Dandot.

The coal which has been most worked in the Punjab is that long known to exist in the Jhelum district, on the Dandot plateau of the Salt range. The only valuable seam varies in thickness from 18 to 39 inches, forming a basin under the nummulitic limestone. The mines at Dandot and at Pidh, 3 miles to the north-east, have been worked for the North Western Railway since 1884. During the period under review, 1898 to 1903, the collieries have shown a decline in output, from a maximum of 81,218 tons in 1899 to 43,704 tons in 1903, and during the last two years the mines have been worked at a loss. The annual output of coal per miner employed at Dandot during the last six years has averaged only 42 tons, against about 75 tons turned out per man in Bengal; but notwithstanding the difficulties connected with mining in this area, the loss of life through accident has been as low, on an average, as 0·74 per 1,000 employés.

Bhaganwala.

The coal near Bhaganwala at the eastern end of the Salt range occurs in a seam of very variable thickness, in consequence of which widely discordant estimates have been made of the resources of the field. Between 1893 and 1898 the field was worked by the North-Western Railway, but the quality of the fuel was poor, and the collieries were worked at a loss. The output amounted to 11,272 tons in 1898, when arrangements were made to dismantle the colliery, which was closed on the 15th January 1899.

Mianwali district.

Some minor works, not beyond the scale of ordinary prospecting operations, have been conducted on the deposits of Jurassic coal in the Mianwali district. The deposits about 2 miles north of Kalabagh are estimated to contain about 72,000 tons of coal, of which less than 1,000 tons a year are extracted. More promising deposits of Tertiary coal occur in the Maidan range, 24 miles further west, but no mining in this locality has so far been attempted.

Bikaner.

A lignite of dark-brown colour, with included lumps of fossil resin, occurs in association with nummulitic rocks at Palana in the Bikaner State, Rajputana. In 1898 mining operations were started at a point where the seam was found to be 20 feet thick, and a branch line, 10 miles long, from the Jodhpur Bikaner Railway, has been constructed to assist the development of the colliery. The figures given in table 17 show a gradual increase of output since 1900, the returns for 1903 being 21,764 tons. The physical characters of the natural fuel form a drawback to its use in locomotives, but experiments recently made are said to show that satisfactory briquettes can be made in which the proportion of moisture is reduced, and the fuel made less vulnerable to atmospheric action.

Labour.

Coal-mining in India, from the point of view of labour, is quite ahead of all other forms of mining. The number of persons employed daily has averaged 84,805 for the years 1898 to 1903, but the returns for 1903 show 9,872 less workers than in 1902, although the output of coal has risen (see table 19). This difference is possibly in part due to a gradually increased precision in the system of making returns, and partly, no doubt, to the fact that the introduction of improved methods in mining is gradually increasing the average efficiency of the miner;

but the sudden rise to an output of 84 tons per person employed, shown in table 20 for the year 1903, is so much in excess of the Giridih return of 72 tons, that there is probably some fault in the returns made of persons employed.

Table 19 shows that 81·8 per cent. of the average number employed during the period have worked in Bengal coal mines, and that the changes elsewhere have been insignificant beside the rise in Bengal from 48,673 in 1898 to 74,538 in 1903.

TABLE 19.—*Number of Persons employed daily in Indian Coal-Mining during the years 1898 to 1903.*

PROVINCE.	1898.	1899.	1900.	1901.	1902.	1903.	*Average.*	Per cent. of average total.
Assam . . .	1,439	1,444	1,350	1,210	1,293	1,255	*1,332*	1·56
Baluchistan . .	238	310	493	635	828	843	*558*	·66
Bengal . . .	48,673	58,130	72,790	79,620	82,545	74,538	*69,383*	81·80
Burma . . .	315	230	279	203	170	80	*213*	·25
Central India . .	1,931	2,354	2,214	2,126	1,723	1,670	*2,003*	2·35
Central Provinces .	1,711	1,852	2,104	2,220	2,337	2,071	*2,049*	2·41
Nizam's Dominions .	6,788	8,490	8,045	7,616	7,538	6,359	*7,473*	8·80
Punjab and Kashmir .	1,879	1,640	1,826	1,536	1,742	1,621	*1,707*	2·01
Rajputana . .	...	...	147	152	136	93	*(a)132*	·16
TOTAL .	62,974	74,450	89,248	95,318	98,312	88,530	*84,805*	100·00

(*a*) Average of three years only.

Effect of coal-mining on the population.

In the parts of Bengal where coal-mining has especially developed, the changes in the population of certain revenue areas since the Census of 1891 have been quite remarkable. The Census of 1901 showed that in the Giridih sub-division of the Hazaribagh district, there had been an increase of 4·0 per cent., part of which, in the Ganwan and Koderma *thánas*, was due to mica-mining, whilst in the Giridih *thána* the increase in ten years was 8·8 per cent. In the Gobindpur sub-division

of Manbhum district, which includes much of the Jherria field, the increase of population between 1891 and 1901 was 25·1 per cent., whilst in the Jherria *thána* itself the increase was 75·1 per cent., and in the adjoining *thána* of Topchanchi the increase, from the same cause, was 30·2 per cent.

Efficiency of the Indian collier.

It will not be surprising to those who know the habits of the Indian coal-miner to learn that the output per person employed is lower than in any part of the British Empire except in Cape Colony, where cheap native labour is largely employed. During the years 1901 and 1902 the outputs of coal per person employed in Indian mines were respectively 70 and 75 tons, whilst for the rest of the British Empire the corresponding figures were 281 and 285 tons (see table 21).

TABLE 20.—*Output of Coal per Person employed at Indian Collieries.*

	1898.	1899.	1900.	1901.	1902.	1903.
Number employed	62,974	74,450	89,248	95,318	98,312	88,530
Tons of coal raised.	4,608,196	5,093,260	6,118,692	6,635,727	7,424,480	7,438,386
Tons of coal raised per person employed.	73	68	69	70	75	84

Death-rate from accidents.

An important consideration, naturally, in every mining community is the risk to life involved in the occupation. As far as coal-mining is concerned in India, the industry, so far as it has progressed, has shown not only a very low death-rate from isolated accidents, but also a noteworthy freedom from disasters, which in European countries have done more, perhaps, than statistics to force special legislation for the protection of workers in "dangerous" occupations. Table 22 shows, for the period 1898 to 1903, the number of deaths from coal-mining accidents in India, compared with the amount of coal raised and the number of persons employed. It will be seen from this table that the average death-rate

from such accidents has been 0·88 per thousand employed, which will compare favourably with the returns for any other country.

TABLE 21.—*Amount of Coal raised per Person employed at Coal Mines in the British Empire.*

COUNTRIES.	1901.			1902.		
	Persons employed.	Tons of coal raised.	Tons per person.	Persons employed.	Tons of coal raised.	Tons per person.
United Kingdom .	792,648	219,046,945	276	810,787	227,095,042	280
New South Wales .	12,191	5,968,426	490	12,815	5,942,011	464
Queensland . .	1,266	539,472	426	1,336	501,531	375
Victoria . .	827	209,329	253	1,303	225,164	172
British Columbia .	3,974	1,460,331	367	4,011	1,397,394	348
Nova Scotia . .	7,663	3,625,365	473	8,062	4,366,869	542
Cape Colony . .	2,588	183,759	71	2,196	165,557	75
Natal . . .	3,397	569,200	168	3,850	592,821	154
New Zealand . .	2,754	1,227,638	446	2,885	1,362,702	472
Transvaal . .	..	...	...	5,439	1,590,330	292
British Empire except India . . .	827,368	232,830,465	281	852,684	243,239,421	285
India . . .	95,318	6,635,727	70	98,312	7,424,480	75

In table 23 (page 43) the results for the rest of the British Empire for the years 1901 and 1902 (the latest years for which complete figures are obtainable) are compared with the corresponding years for India. It will be seen from this that India competes with Queensland for the lowest death-rate, and that the average rate for the rest of the Empire is 1·53 and 1·54 against 0·73 and 0·77 for India. The rate will also compare favourably with the principal foreign coal-mining countries: in Austria the rates for 1901 and 1902 were 1·39 and 1·60 per thousand

PUBLICATIONS

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Palæontologia Indica, arranged in series and sold in parts which are priced at 4 annas (6 pence) per plate.

Memoirs, Vols. I—XXXV, including the larger papers on geological subjects.

Records, Vols. I—XXX, including the shorter papers and Annual Reports from 1885 to 1907, sold in parts price one rupee each.

Mineral Index Maps.

A complete list of the contents of these publications can be obtained by application to the Registrar, Geological Survey of India, 27, Chowringhee Road, Calcutta. Indexes to the Genera and Species described in the Palæontologia Indica up to 1891 in the Memoirs, Vols. I—XX, and in the Records, Vols. I—XXX, have been printed for sale.

GEOLOGICAL SURVEY OF INDIA.

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Empire were respectively 5·42 and 5·41, in India the loss in the same years came to 10·55 and 10·23. It will be noticed, however, that in India the number of persons employed in coal-mining is many times greater than in any part of the Empire, except the United Kingdom itself, where the large number of coal-miners, near 800,000, and the yearly output of more than 220 million tons of coal, together control and tone-out all the irregularities in the returns from the dependencies.

TABLE 23.—*Death-rate from Coal-Mining Accidents in the British Empire.*

	1901.				1902.			
	Number employed.	Deaths.	*Death-rate per 1,000.*	Deaths per 1,000,000 tons coal raised.	Number employed.	Deaths.	*Death-rate per 1,000*	Deaths per 1,000,000 tons coal raised.
United Kingdom.	792,648	1,075	*1·36*	4·91	810,787	1,005	*1·24*	4·42
New South Wales	12,191	17	*1·37*	2·85	12,815	105	*8·01*	17·67
Queensland .	1,266	1	*0·79*	1·85	1,336	1	*0·75*	1·99
Victoria .	827	4	*4·84*	19·11	1,303	1	*0·77*	4·44
New Zealand .	2,754	3	*1·09*	2·44	2,885	2	*0·69*	1·47
British Columbia	3,974	102	*25·67*	69·87	4,011	139	*34·65*	99·48
Nova Scotia .	7,663	14	*1·83*	3·86	8,062	19	*2·36*	4·35
Cape Colony .	2,588	4	*1·55*	21·77	2,196	4	*1·82*	24·16
Natal . .	3,397	43	*12·66*	75·54	3,850	16	*4·16*	26·99
Transvaal . .	...	...	...	...	5,439	23	*4·23*	14·47
British Empire except India .	827,308	1,263	1·53	5·42	852,684	1,315	1·54	5·41
India . .	95,318	70	*0·73*	10·55	98,312	76	*0·77*	10·23

The results for the coal-mines under the control of the Indian Mines Act of 1901 are slightly more favourable than for the total. For the

three years during which the Act has been in operation the average death-rates from accidents at coal-mines under the Act have been as follows:—

1901	0·68	per 1,000.
1902	0·66	„
1903	0·84	„

Mining methods.

The almost universal practice in Indian coal-mines is to extract the coal on the system variously known as the "bord and pillar," "post and stall," or "stoop and room" system. Although this system in Europe is fast being superseded by the more economical "long-wall" method, yet, owing to the thickness of most of the Indian seams, it is not easy to devise any more suitable plan of working. It is undoubtedly wasteful, for the pillars form from 25 to 65 per cent. of the available coal, and at the present time, except in certain mines, where local-trained labour and efficient supervision are possible, their extraction is not even contemplated.

The strong roof so frequently found in the mines worked in Gondwana rocks, due, not only to the intrinsic strength of the rocks, but to the remarkable freedom from geotectonic disturbances on the Peninsula, adds a feature of strength and safety not at once fully appreciated by those who have gained their experience in countries without these advantages, or where the galleries are subject to the stresses of a greater overburden.

In the Giridih coal-field, the system of working thick seams at the East Indian Railway collieries permits of the removal of over 90 per cent. of the coal. As the system here carried out has been subject to careful criticism by English colliery experts, and as it has been shown that the system is perfectly safe under the efficient standard of management and discipline observed at Giridih, workers in other fields are recommended to study the account given by Mr. T. Adamson in his paper on the "Working of a thick coal-seam in Bengal," (*Trans. Min. and Mech. Engineers*, vol. LII, p. 202, 1903).

The system described by Mr. Adamson has been worked for the last twelve years in the Railway Company's collieries at Giridih without a fatal accident being caused by it, but the sandstone roof is an unusually strong one and the coal is free of gas. During the past six years, 1898 to 1903, the average death-rate from accidents of all kinds in these mines has been only 0·40 per thousand persons employed.

The figures given in table 23 for other coal-mining countries will give an idea of the remarkable degree of efficiency in management which this figure indicates.

In the Makum field a highly inclined seam, 75 feet thick, is worked on a modification of the South Staffordshire system of "square work." The coal is removed in two, or sometimes three, sections, the top section being removed first, and a parting of stone and coal being left untouched between each pair of sections. In the Dandot and Khost mines, thin seams are worked in one operation, on a modified "long-wall" system.

Gold.[1]

Comparison with other countries.

India, as shown in table 24, occupies the sixth or seventh position amongst the leading gold-producing countries of the World. The total Indian output is nevertheless comparatively insignificant, aggregating no more than 3½ per cent. of the World's annual supply.

TABLE 24.—*Production, in Ounces, of the Chief Gold-producing Countries for the years 1897 to 1902.*

COUNTRIES.	1897.	1898.	1899.	1900.	1901.	1902.
United States .	2,864,576	3,148,642	3,391,196	3,781,310	3 805,500	3,870,000
Australasia(*a*) .	2,539,491	3,013,763	3,831,937	3,568,279	3,719,103	3,989,083
Canada . .	291,583	662,796	1,018,371	1,350,176	1,183,465	1,003,447
Transvaal . .	2,744,010	3,777,009	3,529,826	348,760	238,991	1,704,410
Russia . .	1,042,017	1,196,634	1,159,214	1,072,434	1,253,592	1,183,379
India . .	390,595	418,944	456,020	512,985	532,126	517,639
Mexico . .	344,518	398,487	448,832	455,204	499,725	546,373
China . .	321,296	21,296	321,510	208,031	145,138	193,517
Korea . .	52,927	55,432	70,954	87,882	111,272	217,706
Brazil . .	70,736	76,613	107,644	127,820	133,636	146,898

(*a*) Includes the six States and New Zealand.

[1] This note on gold has been prepared mainly by my colleague, Mr. J. Malcolm Maclaren, B.Sc., F.G.S.

Table 25 shows the provincial production for India. In 1903 no less than 99¼ per cent. of the Indian output was returned by Mysore. Three-fourths of the remainder was derived from the Nizam's Dominions, leaving only ·18 per cent. as the produce of districts directly under British administration.

TABLE 25.—*Value of Gold produced during the years 1898 to 1903.*

	1898.	1899.	1900.	1901.	1902.	1903.
	£	£	£	£	£	£
Mysore	1,575,966	1,678,463	1,879,085	1,923,081	1,969,448	2,283,999
Nizam's Dominions . .	11,600	33,335	9,375	...	...	14,905
Burma	4,115	4,386	3,327	7,606	5,894	3,988
Madras	10,993	1,261	17	...	...	...
TOTAL (a) .	1,602,691	1,717,445	1,891,804	1,930,687	1,975,336	2,302,492

(a) Exclusive of small quantities obtained by river-washing in various provinces for which accurate returns are not available.

Development of the Kolar Field.

The produce of the Mysore State is solely derived from the Kolar district, and from a single vein or reef in that district—a reef averaging only some four feet in thickness, and payably auriferous for a distance of little more than four miles. As has been the case with all other known auriferous deposits in Peninsular India, the attention of Europeans was directed to this vein by the numerous old native workings along its strike. During the Wainad gold "boom" of 1878-82, several companies with huge capitals were floated to work portions of a concession over the Kolar field. Of the capital subscribed the greater portion was devoted to purchase money, and comparatively little was left for working capital. The features of the auriferous deposits were not at first grasped, and much money was wasted in mining in barren ground and amidst ancient workings, which were eventually found to reach to a depth of 300 feet. All the companies floated with such extravagant hopes in 1881-2 were moribund in 1885, and it was only a dying effort of the Mysore Company in that year that disclosed the great richness of the reef and incidentally the disposition of the auriferous chutes.

By 1887 the adjacent companies had resumed operations, and since

then the history of the field has been one of uninterrupted progress and success. The deepest workings are now somewhat more than 3,000 feet below the surface, and the reef shows, at that depth, little diminution in the value or in the width of the quartz.

Neither mining nor milling offers any serious obstacles on this field. In the former the necessity for heavy timbering and filling to keep the roadways open is perhaps the most serious. The ore is not refractory, and yields its gold to a simple combination of amalgamation and cyaniding.

During the six years under review the annual tonnage crushed has been increased by 62 per cent., from 337,636 tons in 1898 to 546,752 tons in 1903. The gold yield has not shown a corresponding advance, rising only from £1,575,966 in 1898 to £2,284,000 in 1903, an increase of 44·3 per cent. The divergence between the increase of tonnage crushed and the increase of yield therefrom is due to the fact that, with the economies in mining and milling indicated by experience, it is now possible to profitably crush low-grade quartz that ten years ago must have been left in the vein.

For the six years under review the value of gold extracted was £11,310,038, or 60 per cent. of the total value (£18,687,818) extracted in the 21 years since the commencement of work under European supervision. With the increase in output dividends have also increased, rising from £739,114 in 1898 to £1,019,347 in 1903, or an increase of 38 per cent. The total dividends paid during the six years were £4,988,793, or 60 per cent. of the dividends (£8,287,071) paid since 1882, indicating that dividends and output have advanced *pari passu*.

The above dividends have been paid wholly by five companies situated on the line of the Champion reef—the Mysore, Champion Reef, Ooregum, Nundydroog, and Balaghat. A considerable amount of exploratory work has been done by other companies on the Kolar field and elsewhere in Mysore, but hitherto without profitable result.

Of the improvement schemes which will make greatly for the reduction of working expenses, and, to that extent, for the prolongation of the life of the Kolar field, the introduction of electric power from the Cauvery falls is probably the most important. This work was commenced about July 1902, and has since uninterruptedly supplied a little more than 4,000 horse-power to the various mining and metallurgical works. The power is transmitted from the Cauvery Falls over duplicate lines 91½ miles long. The cost to the companies for the first year was

£29 per horse-power, and for succeeding years the cost will be £18. The success of the scheme has led to its enlargement, and works in progress will enable the Mysore Government to materially increase the power available for consumption.

Table 26 shows the various statistics for the Kolar field for the period under review.

TABLE 26.—*Statistics of Production in the Kolar Gold-field.*

YEAR.	Tonnage crushed.	Ounces, bar gold.	Value of gold extracted.	Dividends paid.	Royalty.
			£	£	£
1898 . .	337,636	412,966	1,575,966	739,114	78,009
1899 . .	339,526	446,397	1,678,464	762,600	83,154
1900 . .	401,687	509,272	1,879,085	767,586	93,619
1901 . .	450,272	530,142	1,923,081	874,158	95,219
1902 . .	499,664	533,492	1,969,442	825,928	97,365
1903 . .	546,752	597,884	2,284,000	1,019,347	(a)113,200
TOTAL . .	2,575,537	3,030,153	11,310,038	4,988,793	560,566

(a) Estimated.

Total value of gold produced from 1882 to 1903 inclusive ...	£	18,687,818	11 3
„ „ of dividends paid „ „ „ „ ...	£	8,287,071	7 2
Approximate value of Royalty paid to Mysore Government from 1882 to 1903 inclusive	£	926,334	13 2

The work of the field is carried on by Europeans, Eurasians and Natives in the following proportions, calculated from the number employed during an average year (1902) :—

	Per cent.
Europeans (including Italian miners)	2·05
Eurasians	1·58
Natives : men	89·83
Natives : women (employed only on the surface) . .	6·54

The following table indicates the risks attendant on mining in the Mysore State:—

TABLE 27.—*Showing Fatal Accidents in Mysore Mines for the years 1898 to 1903.*

YEAR.	No. of persons employed.	Death-rate per 1,000 employed.	Death-rate per 100,000 tons quartz crushed.	Death-rate per £100,000 worth of gold obtained.
1898 . .	21,597	2·45	15·70	3·36
1899 . .	21,093	1·80	11·19	2·26
1900 . .	24,587	2·61	15·68	3·35
1901 . .	25,060	2·99	16·65	3·90
1902 . .	26,268	2·21	11·58	2·90
1903 . .	27,355	2·52	11·27	3·02
Average .	*24,326*	*2·43*	*13·67*	*3·13*

Nizam's Dominions.

Outside the Mysore State the only gold quartz mine producing gold at the end of 1903 was the Hutti (Nizam's) mine situated at Hutti in the Lingsugur district of Hyderabad. This company is an offshoot of the Hyderabad (Deccan) Company and was floated in 1901. Crushing with 10 head of stamps was commenced in February 1903, and 3,414 ounces were returned for that year. This result has been considered so promising that the crushing power is being doubled. The workings of this mine give evidence of the remarkable mining skill of the ancients, the auriferous chute having here been followed downwards to a depth of no less than 540 feet.

Another offshoot of the Hyderabad (Deccan) Company was formed in 1898 to work the adjacent mines of Wundalli, and during 1899 crushed 18,790 tons of quartz for a yield of 7,822 ounces. The yield of the Nizam's territory during 1898-99-1900 was almost exclusively the produce of the Wundalli Company. Work was, however, stopped at these mines towards the middle of 1900.

Madras Presidency.

The yield shown from the Madras Presidency was derived from the Mysore (Kangundi) mines in the Kangundi zemindari of North Arcot. Work commenced

here in 1893, and was continued with varying success until 1900. The highest yield obtained was that for the year 1898, *viz.*, 2,854 ounces.

Burma.

During the period under review the only other reef-mining of importance was carried on at the Kyaukpazat mine near Wuntho, in Upper Burma. This mine yielded, in 1898, 1,120 ounces, and maintained, and indeed increased its yield until 1902, when 1,984 ounces, valued at £7,606, were produced. This yield, however, formed merely another example of the general rule that auriferous deposits in andesitic rocks are extremely uncertain in extent and in richness. The pay chute was lost in 1903, and after some exploratory work the mine was closed down.

Alluvial gold-washing is carried on in many places in British India, but from the fact that the washers invariably combine this pursuit with other occupations, and because the individual return is exceedingly small and is locally absorbed for jewellery, complete returns are not available. Returns for 1903 show, however, that 106 ounces of alluvial gold were obtained from the Ladhaki wazirat of the Jammu and Kashmir State. This amount may perhaps be fairly taken as an indication of the annual yield from this portion of the Upper Indus.

Dredging for alluvial gold above Myitkyina on the Upper Irawadi was commenced about November 1902, with a dredger capable of dealing with 10,000 tons a week. The whole of the season (until June 1903) was spent in prospecting the river bed. Five or six spots were thus tried, and the results were considered to be sufficiently satisfactory to warrant an increase of dredgers.

During the past two years surveys of the auriferous deposits of India have been in progress. These, so far as they go, give little hope of the discovery of rich alluvial deposits in Peninsular India, or indeed in any part of India affected by the monsoon rains and dependent on them alone for the supply of the rivers. For concentration of gold a comparatively equable current is essential—a condition rarely obtainable in the gravel river beds of India, where alone gold would be found, for these are almost dry in the cold weather and roaring torrents in the rains. The greater possibilities of dredging on the Irawadi appear to arise from the fact that the waters of that river are derived from ranges where, even in the cold weather, there is a heavy rainfall.

Graphite.

Mode of occurrence.

The graphite deposits of Travancore occur under conditions similar to those of Ceylon, which is but a continuation of the charnockite series and associated rocks of South India. Similar geological occurrences of graphite are found in Coorg, and in the hill tracts of Vizagapatam and adjoining State of Kalahandi. The Ceylon graphite has been made the subject of an elaborate study by E. Weinschenk, who regards it as of igneous origin,[1] a conclusion in agreement with its occurrences in South India.[2]

Production.

Prospecting for graphite has been attempted in the Godavari district, Madras Presidency, and in the Ruby Mines district in Upper Burma, but the only progress made in mining has been in the Travancore State. Regular returns were not available before 1901, but the following figures are returned for Travancore for the remaining three years of the period under review:—

1901	2,490 tons.
1902	4,575 „
1903	3,394 „

Iron.

Notwithstanding the fact, very widely published, that rich deposits of iron-ore occur in India, only one attempt to manufacture iron on European lines has been so far successful, and as it is doubtful if the ores are sufficiently valuable to bear the cost of transport to Europe, no attempt has been made to raise Indian iron-ore for export.

The production of ore is thus confined to that used by the Bengal Iron and Steel Company in its works at Barakar, and the smaller quantities, for which accurate returns are not obtainable, used in the numerous small native furnaces still surviving in parts of Central India, the Central Provinces, Madras, Mysore, and Rajputana. Iron-ore is also used in small quantities in the steel furnaces at the East Indian Railway Company's workshops, Jamalpur.

[1] Die Graphitlagerstätten der Insel Ceylon. Abhand., d. k. Bayer., Akad., 1901, xxi, 279—335.

[2] Holland: The Charnockite series, Mem. Geol. Surv. Ind., XXVIII, 1900, 126; and the Sivamalai series, Mem. Geol. Surv. Ind., XXX, 1901, 174.

The figures returned for Bengal, in which most of the ore used at Barakar is raised, are given in table 28.

TABLE 28.—*Iron-ore raised in Bengal during the years 1898 to 1903.*

YEAR.	Quantity.	Value.	Value per ton.
	Tons.	£	Shillings.
1898	41,854	7,006	3·35
1899	52,000	6,333	2·44
1900	57,000	7,333	2·57
1901	57,800	8,352	2·89
1902	76,056	11,287	2·96
1903	61,355	9,717	3·17
Average .	*57,678*	*8,338*	*2·89*

Up to the present the Barakar Iron and Steel Company has manufactured pig-iron only, of which with two blast furnaces they have turned out about 35,000 tons of pig-iron a year. But a third blast furnace is now in course of erection, and arrangements are complete for starting the manufacture of steel.

Outside Bengal there is very little done in the way of iron-manufacture. The Central Provinces show the largest returns, varying from 2,400 to 4,800 tons, and there is also a sensible industry surviving in Bijawar, Panna, and Orchha, amongst the Central India States, as well as in Mysore and in parts of the Madras Presidency.

Steel is made, both in the form of ingots by the carburization of wrought-iron in crucibles, and, on a much smaller scale, by the decarburization of cast-iron shot in a small open hearth.

Jadeite.

The mineral jadeite, like the jade with which it is often confused, is especially prized by the Chinese, and the quarrying of the mineral forms quite an important industry in Upper Burma. Some of the mineral raised passes by the overland route into South-West China,

whilst most of it finds its way down to Rangoon, whence it is exported to the Straits Settlements and China. The following table shows the extent of this export trade:—

TABLE 29.—*Exports of Jadestone from Burma to the Straits Settlements and China.* (*a*)

Year.	Weight.	Value.	Value per cwt.
	Cwts.	£	£
1897-98	4,036	41,780	10·35
1898-99	4,532	42,120	9·29
1899-00	3,130	58,955	18·83
1900-01	4,531	46,377	10·24
1901-02	3,015	31,713	10·52
1902-03	4,220	47,676	11·06
Average .	*3,911*	*44,770*	*11·45*

(*a*) Overland trade and exports *vid* Rangoon combined.

Value of jade.

Amongst prehistoric relics found in various parts of the World, both jade and jadeite implements and ornaments are widely distributed, and an admiration for the beauty of the stone, descended from a belief in its magical properties, maintains the value of the mineral in the eyes of the Chinese, who are the chief buyers, and to whom the different varieties of both minerals, and possibly some others, are known under the generic name *Yu-esh.* The softer, serpentinous mineral bowenite passes on the North-West Frontier under the name of *Sang-i-yeshm*, and though its characters are unmistakeably distinct from those of jade and jadeite, it is evidently regarded as a poor variety of jade.

Mode of occurrence.

Some jadeite, and often the best material, is obtained as pebbles in the gravels of the Uru river, a tributary of the Chindwin, but most of the material is obtained by quarrying near Tammaw (25° 44′; 96° 14′) in the Mogaung subdivision of the Myitkyina district, Upper Burma. At this locality the jadeite forms a layer in the dark-green serpentine, against which, on a

fresh surface, it stands in striking contrast on account of its lighter colour. The serpentine is apparently intrusive into miocene sandstones, and the jadeite must have been separated as a primary segregation from the magma.

Composition.

There is a general external resemblance between jadeite and jade, or nephrite as it would be more appropriately called, but mineralogically the two are quite distinct. Jadeite is essentially a silicate of soda and alumina, Na_2O, Al_2O_3, $4SiO_2$, with the crystallographic characters of the pyroxene group. Jade is a silicate of lime and magnesia, CaO, $3MgO$, $4SiO_2$, with the essential characters of a hornblende. Their crystallographic characters sufficiently distinguish them in microscopic sections, but in hand-specimens jadeite can be distinguished by its superior hardness and higher specific gravity, as well as by its greater fusibility.

Jadeite occurs in masses of closely interwoven crystals, a structure which gives rise to its great toughness. The purest, though not the most valued, forms are white in colour, but more often there are various shades of green, and, in the case of stones found embedded in the laterite of Upper Burma, there is a red staining often extending to considerable depths in the pebbles, and, in the eyes of the Chinese purchaser, greatly increasing the value of the mineral. The white jadeite with emerald-green spots, caused by the presence of chromium, is also valued greatly for the carving of ring-stones or bracelets.

Prices.

The prices paid for rough stones vary too greatly to permit of an average figure being given, but the export values declared give an idea of the value of the stone: the value so determined has averaged £11-9*s.* per cwt. during the last six years.

No jade (nephrite) of the kind which would be regarded as a marketable mineral is known in India. A mineral having the essential composition, and approaching coarse jade in physical characters, is known in South Mirzapur.[1] True jade, however, has been largely worked in the Karakash valley in South Turkistan for many centuries.[2]

Magnesite.

In South India there are numerous occurrences of the ultra-basic igneous rocks in which olivine is an abundant constituent, and at

[1] F. R. Mallet, Rec. Geol. Surv. Ind., v, 22.

[2] *Cf.* papers quoted by Mallet in Manual, Geol. of Ind., part iv, 1887, p. 85.

several places these highly magnesian silicates have been decomposed with the formation of magnesite of great purity. The largest and best known of these occurrences is near Salem, where the area occupied by the white magnesite veins has been named the "Chalk" hills.

Prospecting operations have been in progress in this area for some years, but the industry may now be described as having passed into the mining stage, and on account of the remarkable purity of the mineral being raised it is expected to command a special price for the preparation of the refractory bricks used for the linings and hearths of steel furnaces, and for lining the fire-bricks of the electric calcium-carbide furnace. The production so far has been small—amounting to 3,540 tons in 1902 and 825 tons in 1903—but work is now being organized on a larger scale.

Manganese-ore.

Production.

The mining of manganese-ore has sprung-up within the last 12 years, and has developed so rapidly that India now takes second place amongst the manganese-producing countries in the World, with an output during the year 1903 of 171,806 statute tons. Table 30 shows the output for each of the past six years and figure 5 (page 13) shows the progress of the mining industry since its commencement.

TABLE 30.—*Production of Manganese-ore for the six years 1898 to 1903.*

YEAR.	Madras.	Central Provinces.	Central India.	TOTAL.	
	Statute Tons.	Statute Tons.	Statute Tons.	Statute Tons.	*Metric Tons.*
1898 . .	60,449	...	...	60,449	*61,419*
1899 . .	87,126	...	...	87,126	*88,524*
1900 . .	92,458	35,356	...	127,814	*129,865*
1901 . .	76,463	44,428	...	120,891	*122,831*
1902 . .	68,171	89,608	...	157,779	*160,311*
1903 . .	63,452	101,554	6,800	171,806	*174,563*

Provincial division.

It will be seen from this table that the mining of manganese-ore was confined to the Madras Presidency until 1899, after which the rich deposits in the Central Provinces were attacked, and are now, notwithstanding their great distance from the coast, providing the chief part of the mineral exported to Europe and America.

Production of foreign countries.

The statistics published by different countries cannot be directly compared, as different definitions of a manganese-ore are followed. According to the rulings of the United States Treasury before 1899, a manganese-ore was so-called only when it carried 50 per cent. of the metal; but in 1899 lower grades were admitted if they contained less than 3 per cent. of iron, and the recognised lower limit is now 44 per cent., those below this grade being generally manganiferous iron-ores. The statistics for 1902 show, in the case of the United States, a total production of 901,214 statute tons of manganiferous iron-ore, but only 16,477 tons came within the Treasury definition of a manganese ore, whilst in the same period as much as 235,576 tons of the 50 per cent. ore was imported. Of the countries which supplied this amount, Brazil contributed 102,550 tons, India 64,170 tons, Cuba 36,294 tons, Turkey 12,609 tons, and Spain 10,464 tons.

Table 31 (on page 57) shows the chief producers of manganese-ore in the World. Of these Brazil has developed as rapidly as India, its output having risen from 14,710 tons in 1896 to 156,269 tons in 1902. Spain, the next producer, for many years turned out over 100,000 tons, but since 1900 has been declining rapidly. Russia has always been the leading producer, the chief source being beds of pure ore interstratified with eocene sands and shales in the province of Kutais.

Distribution of manganese-ore in India.

The mineral is now assuming such importance that it will perhaps be useful for those who are following the developments to put on record a sketch of the distribution in India of deposits considered to be of possible value.

In the Central Provinces, where mining is at present most active, the principal occurrences are in the Ramtek tahsil of the Nagpur district, where in some 17 different villages quarrying operations are being actively carried on. In the north-west part of the Bhandara district there are 14 localities known to contain manganese-ore, and a certain

amount of work is in progress. In the Balaghat district 10 occurrences are known in the west of the district, whilst mining is being carried on near the town of Balaghat, and on another large deposit at Ukua in the Behir tahsil. In Chhindwara manganese-ore is known at 11 localities in the Sausar tahsil, whilst the mineral has long been known near Gosalpur and Sihora in the Jabalpur district. The ore has also been reported from the Khairagarh and Kalahandi States.

TABLE 31.—*Principal sources of Manganese-ore, and latest reported productions.*

Country.	Year.	Production.	Country.	Year.	Production.
		Tons.			Tons.
Russia . . .	1900	884,200	Cuba (Exports) . .	1902	39,628
India	1903	171,806	Chili (Exports) . .	1901	31,477
Brazil (Exports) . .	1902	156,269	France . . .	1901	22,300
Spain . . .	1902	62,944	United States . .	1902	16,477
Turkey (Exports) .	1902	50,000	Japan . . .	1901	15,858
Germany . . .	1902	49,812	Greece . . .	1901	14,166

The deposits in the Central Provinces possibly belong to the same group of rocks which further to the south-east were first worked for manganese-ore in the Vizianagram State, and the intermediate jungle-covered country, which is very little known, will possibly yield further occurrences of the ore on more systematic exploration. In other parts of the Madras Presidency the ore has been reported in the Kallikota State, in the Ganjam district, and in the Sandur hills of Bellary.

One occurrence has been recorded in the Gwalior State, and one is now being worked in Jhabua, from which 6,800 tons were turned out in 1903, whilst there are several localities at which poor ores are found in the Dhár forest.

On the Bombay side, manganese-ores have been found at several places around Mahabaleshwar and Satara; in the southern part of Belgaum district; in Bijapur; near Jambughora in Rewa Kantha; and in the Dharwar district where prospecting operations are in

progress. If the deposits in Dharwar and Belgaum approach those in the Central Provinces in quality, they will, on account of their proximity to the coast, develop very rapidly. Manganese has been reported also in the Tavoy and Mergui districts of South Burma, in the Nizam's Dominions, and in the form of manganiferous iron-ore near Chaibassa in Chota Nagpur.

Mode of occurrence, Nagpur area.

In the Nagpur area the manganese-ore occurs as lenticular masses and bands in the quartzites, schists, and gneisses, and as regards origin appears to have been formed at least partly, by the alteration of rocks composed of manganese-garnet, with which the mineral rhodonite, a manganese pyroxene, is often associated. Consequently the ore is frequently found to pass, both laterally and along the strike, into partly altered or quite fresh spessartite-quartz rock, or rhodonite-spessartite-quartz rock.

Dimensions of ore-bodies.

The ore-bodies often attain great dimensions, and their disposition as irregular lenses along the strike of the enclosing schists naturally influences the miner in laying out the boundaries of his "claims." A deposit near Balaghat is 1¾ miles long; at Manegaon in the Nagpur district the ore-body is 1½ miles long; whilst at Thirori in the Balaghat district it is nearly 6 miles in length. As examples of great breadth may be quoted Kándri, 100 feet thick, of pure ore, and Rámdongri, 1,500 feet of ore and unaltered spessartite (manganese-garnet) rock. The depth of these ore-bodies is quite unknown, as the so-called mining has so far passed little beyond the quarrying stage, and the question of possible exhaustion does not enter into the calculations of the present owners.

Composition.

This Nagpur ore is typically a mixture of braunite, and psilomelane, sometimes, though, entirely braunite—a hard, compact, pure ore, ranging well over 51 per cent. of manganese. The average material now being raised ranges between the following limits on analysis :—

	Per cent.
Manganese	51—54
Iron	5— 8
Silica	5— 9
Phosphorus	0·05—0·12
Moisture	usually below 1·0

The Vizianagram ore occurs under geological conditions apparen

resembling those of Nagpur, though the enclosing rocks are sometimes too decomposed for precise petrological determination. There is another mode of occurrence in the Nagpur district, the ore occurring as nodules in crystalline limestone associated with piedmontite, and in places where there has been a dwindling of the limestone through water-action, these nodules of ore have accumulated in layers of a size which might be worth working. Occasionally in cavities in this limestone beautiful pyrolusite crystals are found.

Being near the coast, and consequently free of the tax of railway freight, it is possible to export a lower grade of ore from Vizianagram than from the Central Provinces. The ores shipped from Vizianagram show, according to Mr. H. G. Turner (*Journ. Iron and Steel Inst.*, 1896, I, 160) the following range of composition :—

Manganese	45—50 per cent.
Iron	7—13 „
Silica	2— 5 „
Phosphorus	0·12— 0·27 „
Moisture	1·10— 1·80 „

Jabalpur.

Manganese-ore occurs under different conditions in the Jabalpur district, where it is found in the Dharwar-like schist series which forms a belt with a maximum width of 7 miles stretching for 20 miles in a N.E.—S.W. direction. The rocks in this belt are various quartzites, phyllites, and schists, including hematite-schists and jaspers. The hematite-schists are slightly manganiferous and are often capped by a secondary deposit of limonite, in which psilomelane has formed into irregular nodules. Pyrolusite and psilomelane also occur in this district, sometimes occupying cavities in a siliceous breccia which is rather common.

Mahabaleshwar.

The manganese-ore occurring in the neighbourhood of Mahabaleshwar forms irregular nodules distributed through the laterite cover on the Deccan Trap, and the nodules are formed presumably by concentration of the residue from the action of meteoric waters on the basaltic rocks.

Valuation of manganese-ore.

For use in steel-making, manganese-ores should contain not more than 0·15 per cent. phosphorus nor more than 10 per cent. of silica. Under conditions laid down by the Carnegie Steel Company, ores containing less than 40 per cent. manganese and more than the above-mentioned quantities of phosphorus and silica may be rejected at the option of the

buyer. Deductions from the scheduled price per unit are made also for every 1 per cent. of silica above 8 per cent. and for each 0·02 per cent. of phosphorus in excess of 0·1 per cent. Steel manufacturers pay an additional price per unit of iron present in the ore.

TABLE 32.—*Variation in the Price of Manganese-ore c. i. f. at United Kingdom Ports.*

Date.	50 per cent. Mn. and upwards.	47—50 per cent. Mn.	40—47 per cent. Mn.
	Pence per unit.	Pence per unit.	Pence per unit.
January 1898	9—12	8½—11	7½—10½
July 1898	9—12	8½—11	7½—10½
January 1899	10—12½	9—11	7½—10½
July 1899	12—14	10½—11½	8—10
January 1900	13—15	12—13	10—12
July 1900	13½—15	11½—12½	10—12
January 1901	12—14	11—12	10—11
July 1901	10½—11	9—10	—8
January 1902	9½—10½	9—9½	8—9
July 1902	9½—10½	9—9½	8—9
January 1903	10—10½	8½—9	7½—8½
July 1903	10—10½	8—9	7½—8½
January 1904	9—9½	8—9	6—8

Prices.

The prices paid for manganese-ore carrying over 50 per cent. of the metal, delivered at United Kingdom ports or at New York, ranged between 9 and 10 pence per unit at the end of 1903. Thus, an ore with 52 per cent. manganese

would be valued at $\frac{52 \times 9}{12} = 39$ shillings a ton. Table 32 (page 60) and the following diagram (figure 9) show the recent variations in the prices of ore of different grades:—

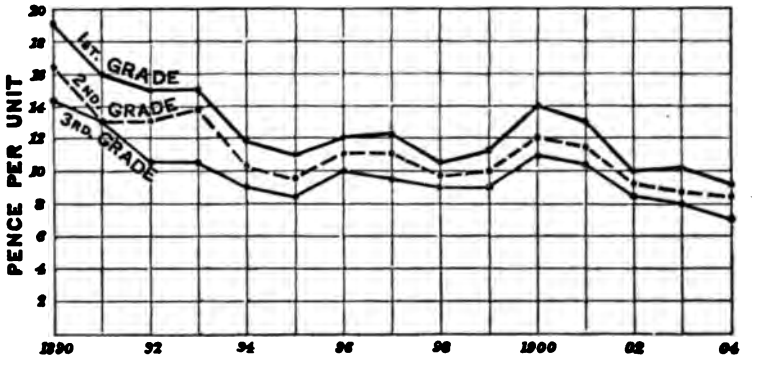

FIG. 9.—*Variation in the Prices of Manganese-ore at United Kingdom Ports since 1890.*

Economic considerations.

Owing to the distance of the chief deposits from the sea-board—amounting in the case of the Central Provinces to about 500-600 miles—and the heavy freight charges to Europe and America, only the high grades of ore can be touched. Ores which would be considered valuable within range of a steel-making centre are rejected in India, and the result is a regretful waste of the natural resources, which will continue until there is a demand in the country for ferro manganese and facilities for its manufacture. As the ore sent out of India ranges a little over 50 per cent. of manganese, the metal for which it is valued is charged with nearly double freight; but the present owners of mines have so far sunk comparatively little capital, and the so-called mines are mere open quarries worked by the assistance of no expensive plant; there is thus no present inducement for husbanding resources, and there will probably be no attempt, either to manufacture ferro-manganese from low-grade ores, or to make steel, before the inevitable decline in the mining industry takes place. There is now an apparent haste to make the most of the present circumstances, and as the Indian and Brazilian outputs have already affected the market, there is a very evident fear of depreciation in prices, and consequent curtailment of the life of the industry; for

the export of manganese-ore will cease to be profitable long before the natural stocks of higher grades of ore are exhausted—when, in fact, quarrying passes into mining, and the simple excavation of rich ore now in sight in great quantities gives place to the more expensive process of selection. However, by all accounts and all appearances, there is yet a fair future before the present owners of manganese-ore quarries, and the wonder is, not that manganese-ore mining has developed so greatly in India, but that such rich deposits could have remained so long prominently exposed and yet untouched, as attention was directed to the best of them many years ago.[1]

One cannot help the feeling of regret that the whole industry is at present equivalent to a heavy loss to the country. The ore exported is worth perhaps Rs. 30 a ton in the country to which it is sent: this country gets out of it merely the margin left after paying the heavy freight charges, and possibly Rs. 15 a ton can be regarded as the profit to India, divided between the railways, the miners and the owners of the land. At the same time, India has to pay the foreign manufacturer's profits and the cost of return carriage for the manganese brought back in the form of steel. If a flourishing steel-manufacturing industry existed in the country, much of the manganese would be retained in India, and the lower-grade ores also would be economically developed. As it is, our manganese-ore is being exported to the three great steel-producing countries—England, United States, and Germany. The exports to Holland and Belgium shown in table 33 are in part for transmission to Germany, whilst the consignments sent to Egypt were booked to Port Said to await orders for delivery to ports further west.

Uses of manganese-ore.

It is only, however, within recent years that the demand for manganese in steel-making has grown so rapidly. Manganese-ore was formerly used in the chemical trade in various ways, but mainly for the production of the chlorine necessary to manufacture bleaching powder: it was then valued especially for its content in oxygen, in which respect the Indian braunite is inferior to pyrolusite. Now the conditions are reversed, and the ore being valued mainly on account of its manganese content, the sesquioxide, in braunite, which predominates in the Indian deposits, is more valuable than the dioxide, pyrolusite.

[1] V. Ball, Manual of the Economic Geology of India, 1881, 329.

TABLE 33.—*Distribution of exported Indian Manganese-ore for the years 1897-98 to 1902-03.*

COUNTRIES.	1897-98.	1898-99.	1899-00.	1900-01.	1901-02.	1902-03.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
United Kingdom	54,279	51,931	63,175	86,269	65,150	95,540
Belgium . .	...	...	5,350	13,300	...	1,000
France . .	...	...	...	5,850	...	...
Germany . .	...	...	...	...	11,300	10,734
Holland . .	...	..	8,350	16,500	...	5,050
Egypt . .	...	...	...	3,400	15,000	...
United States .	24,550	10,900	18,350	5,350	41,720	42,950
TOTAL .	78,829	62,831	95,225	130,669	133,170	155,274

Mica.

Incomplete returns for production.

The returns of production for mica grossly understate both quantity and value, as both are below the export returns. As the only mica on which royalty is charged is that raised in Government land, and as many mica miners have mines in both Zemindari and Government land, there are obvious reasons for understating the production, and, besides this fact, the flourishing industry of stealing mica diminishes the returns for production without affecting the export figures.

Exports.

A considerable quantity of mica of the poorer grades is consumed in the country for ornamental and decorative purposes, and a small quantity of the larger sheets is used for painting pictures on in various parts of the country. As far as the figures for *quantity* are concerned, therefore, the exports cannot be accepted as an approximate expression of the production; but as regards *value,* the export returns may be accepted as a closer approach to the figures which should express production.

Variations in value.

From table 34 it will be seen that, during the years 1897-98 to 1902-03, the mica exported averaged 19,173 cwts., and had an average annual value of

£77,613, or £4·05 per cwt. The variations in yearly value reflect a serious change in the trade which occurred in 1899. The diagram forming figure 6 (page 14) brings out this feature very strikingly. In 1898 Indian mica miners began to realize that their waste dumps contained a large supply of the material wanted for the manufacture of micanite, in which thin films of mica are cemented together and moulded into sheets, to serve many purposes for which the natural sheets only were used formerly. The waste heaps were consequently turned over, and the clear sheets of muscovite cleaned and split into thin films by gangs of children, who, by practice, could select the films of the required thickness with an accuracy which could scarcely be exceeded by the use of a micrometer. The large quantities of "flimsy" mica thus suddenly thrown on to the market raised the weight of mica exported, without a corresponding increase of value. Thus, figure 6 shows the curve for weight, suddenly rising in the years 1899—1901 until it crosses that for value, falling back with the reaction in the following year, but with a closer approximation of the two curves marking the years subsequent to 1901 when compared with those before 1898.

Export of films for micanite.

TABLE 34.—*Exports of Indian Mica during the years 1897-98 to 1902-03.*

YEAR.	Quantity.	Value.	Value per cwt.
	Cwts.	£	£
1897-98	11,608	71,234	6·14
1898-99	10,947	53,890	4·92
1899-00	22,599	73,372	3·25
1900-01	33,175	109,554	3·30
1901-02	16,298	70,034	4·30
1902-03	20,412	87,594	4·29
Average .	*19,173*	*77,613*	*4·05*

The same lesson is expressed in table 34, from which it will be seen that the average value of the mica sent out of the country in 1897-98 was £6·14 per cwt., and that this value dropped down to £3·25 in

1899-1900, when the cheaper mica was exported in quantity, with only a partial recovery in the following years, during which both the cheap kinds and the more expensive sheets were exported together.

Source of mica raised for export.

Table 35 shows the relative contributions of the mica exporting provinces, and in the case of Bengal and Madras the only provinces in which the industry can be regarded as established, the mica exported was that produced within the Presidency in each case. It will be seen from this table that, during the years under review, the two chief producers contributed to the average total as follows:—

Bengal . . .	12,282 cwts., valued at .	. £52,272
Madras . . .	6,872 „ „ .	. £25,241

The average value of the mica sent out of Bengal was thus £4·26 per cwt., whilst that from Madras was £3·67.

TABLE 35.—*Exports of Mica for the years 1897-98 to 1902-03.*

YEAR.	BENGAL.			BOMBAY.			BURMA.			MADRAS.		
	Weight.	Value.	Value per cwt.	Weight.	Value.	Value per cwt.	Weight.	Value.	Value per cwt.	Weight.	Value.	Value per cwt.
	Cwt.	£	£	Cwt.	£	£	Cwt.	£	£	Cwt.	£	£
1897-98	8,344	50,051	5·99	...	...	...	...		...	3,264	21,183	6·49
1898-99	7,720	31,954	4·14	11	50	4·55	10	258	25·8	3,706	21,628	6·75
1899-00	15,473	47,234	3·05	51	90	1·76	3	13	43·3	7,071	26,035	3·68
1900-01	13,633	63,049	4·62	25	100	4·00	...	...	...	19,517	46,405	2·38
1901-02	11,870	53,140	4·48	7	19	2·71	...	...	...	4,421	16,875	3·82
1902-03	16,651	68,202	4·10	6	72	12	...	...	...	3,755	19,320	5·15
Average	*12,282*	*52,272*	4·26	*20*	*66*	3·30	*3*	*54*	18·00	*6,872*	*25,241*	3·67

Distribution of mica exported.

Table 36 shows the average distribution of exported mica during the period under review. It will be noticed that the United Kingdom took the largest share, amounting to 73·2 per cent. of the average total

policy then described is beginning now to impress itself on the mica-miners, who will be fortunate if no other country steps in to secure the market which could be controlled by India, or no artificial substance is found to meet the growing demand for mica, before the miners learn the necessity for reorganizing their methods.

Prospecting rules.

The rules for the grant of prospecting licenses and mining leases for mica in Bengal were revised in April 1902, and are printed *in extenso* with those for Madras in the Memoir on Indian Mica published by the Geological Survey in 1902. The important changes introduced in the rules were:—

(1) The levy of a royalty in the case of prospecting licenses at the rate of 5 per cent. on the sale value of mica;
(2) The abolition of the system of putting up leases of mica mines to auction, and provision for restricting operators to approved methods;
(3) The raising of the maximum period of leases to 30 years;
(4) The grant of power to lessees to relinquish their grants during the currency of their leases.

Prospecting licenses granted.

Of the prospecting licenses issued during the period under report, seven were granted in Nellore, four in Coimbatore, one in Godavari, and one in the Tinnevelly district, Madras Presidency. In the Central Provinces, one was granted in each of the three districts, Balaghat, Hoshangabad, and Chhindwara. In Burma, one license was issued for each of the two districts of Magwe and Mandalay, and two each for Myitkyina and the Ruby Mines district. In Assam, one license was granted in the Khasia and Jaintia hills. In Rajputana, four licenses were granted in Ajmer-Merwara, making a total of 27 licenses, covering 3,223 square miles.

Labour statistics.

Most of the mica mines having come under the control of the Indian Mines Act of 1901, labour statistics for the last three years of the period under review are now available. These are summarised in table 38, from which it will be seen that the mica industry comes next to gold in providing labour, whilst the risks attending mica-mining, as now practised, are rather greater than those of coal mining in India, though the period is too short for a fair comparison of the two industries.

had an average annual value of £33,481, those for the following five years averaged £61,880.

The tariff, however, naturally affected the Indian producer, who then contributed the chief part of the mica consumed in America, whilst the practice of preparing the mineral for the market became affected by the classification adopted, though some Indian producers were slow in observing the fact that mica sent to the London market in neatly trimmed rectangles was, on account of the higher duty, worth slightly less to the American buyer than the roughly dressed material.

Competition with Canada.

For many years India met with little competition from other countries in the American market, but during the last two years Canada has produced large quantities of phlogopite, and by meeting the requirements of the consumers of mica, has seriously challenged the supremacy of India. Table 37 shows approximately the relative positions of the three countries which, between them, produce well over 90 per cent. of the World's supply. India has so far enjoyed an easy lead, but there was a sudden expansion of the Canadian output in 1902, though reports recently received forecast a return to near the normal value of £32,000 for the year 1903.

TABLE 37.—*Value of Mica raised in the three principal producing countries.*

YEAR.	1898.	1899.	1900.	1901.	1902.	*Average.*
	£	£	£	£	£	£
India (*a*) . .	53,890	73,372	109,554	70,034	87,594	*78,888*
United States (*b*)	26,219	24,293	29,592	23,715	23,769	*25,518*
Canada . .	24,324	33,493	34,110	32,877	(*c*)82,192	*41,399*

(*a*) Exports only. | (*b*) Value at the place of production.
(*c*) Preliminary figures subject to revision.

Mining methods.

The methods of mining and the distribution of mines do not differ materially from those described in a special Memoir issued two years ago.[1] The short-sighted

[1] T. H. Holland: The Mica Deposits of India. Mem. Geol. Surv. Ind., vol. XXXIV, part 2, 1902.

policy then described is beginning now to impress itself on the mica-miners, who will be fortunate if no other country steps in to secure the market which could be controlled by India, or no artificial substance is found to meet the growing demand for mica, before the miners learn the necessity for reorganizing their methods.

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TABLE 38.—*Labour Statistics of Mica Mines for the years 1901 to 1903.*

	Province.	1901.	1902.	1903.	*Average for 3 years.*
Number of persons employed.	Bengal .	6,254	7,363	6,464	*6,694*
	Madras .	2,965	21,137	2,312	*2,471*
	TOTAL .	9,219	28,500	8,776	9,165
Number of Deaths from Accidents at Mica Mines.	Bengal . .	2	2	9	*4·33*
	Madras .	16	...	...	*5·33*
	TOTAL .	18	2	9	9·66
Death-rate per 1,000 persons employed at Mica Mines.	Bengal . .	0·32	0·27	1·39	*0·65*
	Madras .	5·39	...	...	*2·16*
	Average .	*1·95*	*0·21*	*1·02*	*1·05*

Petroleum.

Total production.

More progress has been made, during the period under review, in developing the petroleum resources than those of any other mineral.[1] The output in 1897 amounted to 19 million gallons, and at the time was a record production, but the outturn has since been quadrupled, and in 1903 amounted, as shown in table 39, to nearly 88 million gallons.

Position of India amongst oil-producing countries.

But still India contributes little more than 1¼ per cent. of the World's supply of mineral oil.[1] Figures for all other countries are not yet obtainable for 1903, but table 40 (page 71) shows the position India occupied amongst oil-producing countries in 1901 and 1902, when its output exceeded 50 million gallons. With the United States and Russia overwhelming all others by producing over 90 per cent. of the World's supply, India takes a place amongst the second group of producers, and at the present rate of expansion will soon be competing with the Dutch East Indies, where the oil-fields are situated on a geological extension of the Assam-Burma belt.

[1] Preliminary returns for 1903 show that the Indian output was 1·29 per cent. of the World's total supply. (*Petroleum Review*, Oct. 22, 1904, p. 330.)

TABLE 39.—*Production of Petroleum during the years 1898 to 1903.*

YEAR.	QUANTITY.		VALUE.
	Gallons.	*Metric tons.* (*a*)	
			£
1898	22,234,438	*89,295*	76,821
1899	32,934,007	*132,265*	125,684
1900	37,729,211	*151,523*	148,755
1901	50,075,117	*201,105*	204,342
1902	56,607,688	*227,340*	217,816
1903	87,859,069	*352,848*	354,365

(*a*) The metric ton is assumed to be equivalent to 249 gallons of crude petroleum having a specific gravity of 0·885.

Imports.

India is, however, still far from meeting all its own requirements in mineral oil. The imports during the past six years have averaged nearly 85½ million gallons, valued at £2,314,891 (table 41, page 72), but the fall after the maximum of 1901-02 was continued into 1903-04, and it now appears, consequently, that foreign supplies are actually being displaced. It is interesting to notice that, of the two great producers, Russia and the United States, which have been supplying between them 93·5 per cent. of the imported foreign oil, Russia has been gradually increasing its predominance over the United States in the Indian market. In 1897-98 Russia contributed 58·1 per cent. of the imports and the United States 29·7 per cent., but in 1901-02 the former had secured 85·5 and the latter only 9·5 per cent. of the Indian custom, though a slight reversal occurred in 1902-03 (see table 41).

Value of imports.

As shown in table 42 (page 73), the predominance of Russia as a supplier of mineral oil to India is more a matter of quantity than of value, for although both countries supply large quantities of the cheaper kinds of oil, the supplies of more expensive kerosenes come from America, and the average price per gallon of the American oil is greater than that from Russia, prices on the whole having been enhanced in the former case from an

average of 6·66 pence per gallon in 1897-98 to 7·81 pence per gallon in 1902-03, and having been depressed in the case of Russian oil from an average of 6·47 pence per gallon in 1897-98 to 5·93 pence in 1902-03.

TABLE 40.—*World's Production of Petroleum in 1901 and 1902.*

COUNTRIES.	1901.		1902.	
	Gallons.	*Per cent. of Total.*	Gallons.	*Per cent. of Total.*
United States . .	2,428,621,790	*41·84*	3,106,842,060	*47·94*
Russia . . .	2,980,899,460	*51·38*	2,818,901,575	*43·50*
Sumatra, Java and Borneo.	106,354,500	*1·84*	205,100,000	*3·17*
Galicia . . .	113,804,040	*1·96*	144,975,600	*2·24*
Roumania . .	49,215,600	*0·85*	72,097,550	*1·11*
India . . .	50,075,117	*0·86*	56,607,688	*0·87*
Japan . . .	38,500,000	*0·67*	41,755,000	*0·64*
Canada . . .	20,037,500	*0·35*	18,200,000	*0·28*
Germany . . .	10,977,050	*0·19*	12,378,625	*0·20*
Peru . . .	2,529,135	*0·04*	2,100,000	*0·03*
Italy . . .	353,500	*0·02*	420,000	*0·02*
Other Countries .	700,000		910,000	
TOTAL .	5,802,067,692	*100·00*	6,480,288,098	*100·00*

Occurrences of Indian petroleum.

The petroleum resources of India are confined to the two systems of folded rocks at either end of the Himalayan arc—

(1) The Iranian system on the west, including the Punjab and Baluchistan, and continued beyond British limits to Persia, where the oil-fields have attracted interest for many years.

(2) The Arakan system on the east, including Assam and Burma, with their southern geotectonic extension to the highly productive oil-fields of Sumatra, Java, and Borneo.

TABLE 41.—*Origin of Foreign Mineral Oil imported into India during the years 1897-98 to 1902-03.*

Countries.	1897-98.		1898-99.		1899-00.		1900-01.		1901-02.		1902-03.		Average.	
	Gallons.	Per cent. of Total.	Gallons.	Per cent. of Total.	Gallons.	Per cent. of Total.	Gallons.	Per cent. of Total.	Gallons.	Per cent. of Total.	Gallons.	Per cent. of Total.	Gallons.	Per cent. of Total.
Russia . .	50,672,226	58·1	50,940,879	62·2	57,658,254	76·9	67,350,856	83·4	84,514,016	85·5	71,197,917	80·1	63,722,358	74·6
United States.	25,967,322	29·7	23,602,079	28·8	15,043,622	20·1	9,798,257	12·1	9,437,107	9·5	13,425,470	15·1	16,212,310	18·9
Other Countries.	10,685,478	12·2	7,408,514	9·0	2,257,557	3·0	3,639,469	4·5	4,935,082	5·0	4,249,857	4·8	5,529,326	6·5
TOTAL .	87,325,026	100·0	81,951,472	100·0	74,959,433	100·0	80,788,582	100·0	98,886,205	100·0	88,873,244	100·0	85,463,994	100·0
Value .	£ 2,433,976		£ 2,163,152		£ 2,120,086		£ 2,304,562		£ 2,557,882		£ 2,309,151		£ 2,314,801	

TABLE 42.—*Average Annual Value of Mineral Oil imported during the years 1897-98 to 1902-03.*

COUNTRIES.	Average annual value.	Average value per gallon.
	£	Pence.
Russia	1,666,571	6·28
United States . . .	483,220	7·22
Other Countries . . .	165,011	7·17
Average Annual Total and Average Price.	2,314,802	6·50

In both areas the oil is associated with Tertiary strata, and has had probably similar conditions of origin in both cases, but the structural features of these areas are not equally suitable for the retention of oil in natural reservoirs. In Burma, however, the conditions have been locally ideal: the well-known Yenangyaung field lies in a N. N. W.—S. S.E. flat anticline, the axis of which by variation in pitch has produced a flat dome in the Kodaung tract. The rocks in this dome include a porous sand at depths of 200—300 feet, covered by impervious clay-beds, which have helped to retain the oil until the impervious layers are pierced by artificial wells. In the Baluchistan area the rock-folds have been truncated by agents of denudation, or have been dislocated by earth-movements, and much of the original stores of oil have disappeared. Oil-springs are common enough, but they are mere "shows," not connected with reservoirs which can be tapped by artificial means.

Punjab.

In the Punjab, oil-springs have been known for many years to exist in the Rawalpindi district and further to the south-west, but the total output of the Punjab is small, ranging between 1,000 and 2,000 gallons a year. During the past six years the recorded production has been as follows:—

1898	1,510 gallons.
1899	1,104 „
1900	1,874 „
1901	1,812 „
1902	1,949 „
1903	1,793 „

Baluchistan.

Unsuccessful attempts have been made to develop the oil resources indicated by springs in different parts of Baluchistan; the most prominent of these are near Khatan in the Mari hills and Moghal Kot in the Sherani country, where small oil springs which were examined in 1891 were found to yield oil of a very high quality. The oil-spring in the neighbourhood of Moghal Kot affords a good illustration of the way in which a country, originally well endowed with the necessary conditions for the natural production of petroleum, may lose its resources by subsequent destruction of the natural reservoirs. The Moghal Kot oil-bearing beds form a very open anticlinal fold, whose axis pitches to the E.N.E., and if the dome possessed the necessary plastic, impervious envelope, the oil rising up from below would have become concentrated in the porous beds which form the saddle, but for the fact that along this line the rocks are more easily eroded by surface water, and the anticline thus forms the gorge of a river by which the rocks have been opened to permit the waste of oil for an indefinite time. This is, unfortunately, the history of most of Baluchistan and the Punjab, where the oil-bearing strata are either disturbed beyond the plastic limit of the impervious layers, or the whole series of beds (those which are porous and hold the oil, as well as those which are impervious and limit its movements underground) have been exposed to the air. In this respect the Punjab-Baluchistan area offers fewer prospects of success than the eastern group of Assam and Burma, where, especially in the latter area, the rocks are less disturbed and the softer shales have retained their nearly impervious character.

Up to the present, however, all attempts to develop the oil prospects of India have been without success, except in Burma and North-East Assam. Burma holds an easy lead, and if its resources hold out, the present rate of development will soon displace foreign supplies.

Assam.

The delay in the development of the promising petroleum resources of Assam is an instance of a remarkable diffidence and want of enterprise existing in a commercial community which could show the reckless speculation of the gold boom of 1890. As long ago as 1865 an account of the Makum area was published by Mr. H. B. Medlicott, F.R.S., in the Memoirs of the Geological Survey, and trial borings were then recommended. This advice was followed in 1867, when a Calcutta firm obtained permission to prospect, and struck a promising oil-spring at a depth of 118

feet near Makum; but nothing more was done until 1883, and only very slow development occurred in the following sixteen years. The Assam Oil Company was, however, formed in April 1899 with a nominal capital of £310,000, most of which was quickly called up and invested in the erection of a new refinery at Digboi and in systematic drilling operations, with the result that the output rose from 631,571 gallons in 1901 to 2,528,785 gallons in 1903. Besides the ordinary illuminating oil and solid paraffins, the Assam Oil Company has made a successful attempt to put petrol on the Indian market. The following table shows how the output in this area has been rising during the last six years:—

1898	547,965	gallons.
1899	623,372	„
1900	753,049	„
1901	631,571	„
1902	1,756,759	„
1903	2,528,785	„

The belt of Tertiary rocks extending from the north-eastern corner of Assam for some 180 miles south and west shows frequent signs of oil, nearly always in association with coal and sometimes associated with brine-springs and gas-jets. The series of earth-folds in which this corner of Assam occurs stretches southwards to Cachar, where oil springs are also known, through the little-known Lushai hills into Arakan, and in the same system of parallel folds occur the oil-fields of the Arakan coast on one side of the Yoma and those of the Irawadi valley on the other (see plate 6).

Burma.

The most productive oil-fields of Burma are those on the eastern side of the Arakan Yoma, in the Irawadi valley, forming a belt stretching from the Magwe district, in which the well-known field of Yenangyaung occurs, through Myingyan, in which Singu occurs, across the Irawadi into Pakokku, where Yenangyat is situated. Oil is, however, known further south in Minbu, Thayetmyo and Prome, and further north in the Chindwin valley, but these areas have not so far been thoroughly prospected, and the great development which has recently taken place has been the direct outcome of work in the three fields, Yenangyaung, Yenangyat, and Singu.

Yenangyaung.

Yenangyaung, the best known and most developed of the fields, still holds the lead as a producer. The oil in this area has been worked by native wells on both

sides of the dome for well over 100 years, and before 1886 the annual yield was generally over two million gallons, but soon after systematic drilling was introduced in the central Kodaung tract in 1887 the output gradually rose to over 10 million gallons in 1894, and last year, 1903, reached a record of 56,920,662 gallons.

TABLE 43.—*Production of the Burma Oil-fields between 1898 and 1903.*

YEAR.	Yenangyaung, Magwe District.	Singu, Myingyan District.	Yenangyat, Pakokku District.	Akyab.	Kyaukphyu.	TOTALS.	
	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	*Metric tons.*
1898 . .	15,484,301	...	6,036,088	58,025	105,549	21,684,963	*187,088*
1899 . .	22,111,514	...	10,030,790	50,559	116,668	32,309,531	*129,757*
1900 . .	27,123,325	...	9,701,769	36,852	112,342	36,974,288	*148,491*
1901 . .	37,482,935	...	11,843,341	22,355	93,103	49,441,734	*198,561*
1902 . .	40,712,142	174,880	13,824,390	36,794	100,774	54,848,980	*220,277*
1903 . .	56,920,662	5,617,381	22,665,518	52,968	71,962	85,328,491	*342,685*
Average .	*33,305,813*	*2,896,130* (a)	*12,350,316*	*42,926*	*100,233*	46,764,665	*187,810*

(a) Two years only.

Yenangyat.

Yenangyat yielded very small supplies of petroleum before 1891, when drilling was started by the Burma Oil Company. The expansion was slow until 1894, when 324,086 gallons were produced, but rose rapidly to 6,036,088 gallons in 1898 and to 22,665,518 gallons in 1903. The oil from the Yenangyat area, and that from its southward extension on the other side of the Irawadi river near Singu, contains a higher proportion of the lighter hydrocarbons than the Yenangyaung crude oil.

Singu.

Singu has suddenly come into prominence. Petroleum was first struck by the Burma Oil Company in this area on the 30th October 1901, and arrangements were then made to provide tanks for its reception. Production did not consequently begin till 1902, when only 174,880 gallons were turned

out with the opening of the new wells, but the output jumped up to 5,617,381 gallons in 1903. The crude oil first obtained had a specific gravity of 0·8247 and flash point under 40° F., in consequence of which primary stills were erected on the field to remove the light naphthas before transport to the Rangoon refineries.

Arakan coast.

Besides the Upper Burma oil-fields, the islands off the Arakan coast, noted for their mud volcanoes, have also been known for many years to contain oil deposits of uncertain value. The chief operations have been carried on in the Eastern Barongo Island near Akyab and on Ramri Island in the Kyaukphyu district. During the past six years the average output of the former area has been 42,926 gallons, whilst in Kyaukphyu the output in the same period has averaged about 100,000 gallons, with a distinct tendency to decline.

Bulk system of transport.

The main factor which has contributed elsewhere to the recent great advances in oil production, namely, the general adoption of the bulk system of transport and distribution, has been receiving the attention of those interested in the development of the Burma oil-fields. The Burma Oil Company have laid a pipe-line from Yenangyat, through Singu, to the Yenangyaung area, and are now preparing to connect all the fields in a similar way with their refineries in Rangoon, a distance of 275 miles; they are adding several large tank steamers to their present fleet of five, with storage tanks at the principal Indian ports. The enterprise shown in the laying out of capital in Burma evidently anticipates an expansion in the trade well beyond the record output of 1903, and the fact that mineral oil is being rapidly adopted as fuel instead of coal, removes the fear of over-production which seemed likely as long as petroleum was used only as an illuminant.

Ruby.

During the period under review the ruby-mining industry in Upper Burma underwent a new and favourable phase, the mineral having become, next to petroleum, the most profitable source of revenue amongst Burmese minerals. Various leases were granted in the ruby-bearing area near Nanyaseik in the Myitkyina district, and in the "stone-tract" of the Sagyin hills, in Mandalay district, and the results have been mostly profitless; but the returns for the Mogok area, where the Burma

Ruby Mines Company is paramount, show that the industry has entered a most encouraging phase. The Company was granted the right in 1889 to mine for rubies and to levy royalties from persons working by native methods, the lease being renewed in 1896 for 14 years, at a rent of Rs. 3,15,000 a year *plus* a share of the profits. The results being, however, unsatisfactory from the shareholders' point of view, the rent was reduced in 1898 to Rs. 2,00,000, the share of the profits being, at the same time, raised from 20 to 30 per cent. A dividend of 5 per cent. was paid for the first time in 1898, when the value of the rubies obtained amounted to £57,950. In 1899 the Company obtained rubies to the value of £90,848 and paid a dividend of 12½ per cent.: in this year three unusually valuable stones were found, one of 77 carats being valued at 4 lakhs of rupees (£26,666). In the following year, 1900, the value of the stones raised increased to £97,326, and the Company paid a dividend of 17½ per cent. The year 1901 showed the record output of stones valued at £104,476, whilst in 1902 they brought £86,895. In the last year, 1903, the Company's receipts were £98,575, and profits on the year's working £44,950.

Salt.

Origin of Indian salt.

There are three kinds of sources from which salt is produced in India:—

(1) Sea-water, from which 61·8 per cent. of the total production was obtained during the period under review;

(2) Sub-soil water and lakes in areas of internal drainage, in both of which the origin and mode of concentration of the salt are the results of essentially similar natural processes. From these sources about 27 per cent. of the total was obtained; and

(3) Rock-salt beds, from which 11·2 per cent. of the total was obtained by mining and quarrying.

Production.

During the past six years, 1898 to 1903, the average annual production of salt in India amounted to 979,572 statute tons. Table 44 shows the variations for the past six years and plate 4 shows graphically the position India has taken amongst the large salt-producing countries during the past 22 years.

TABLE 44.—*Production of Salt in India (excluding Aden).*

YEAR.	Statute Tons.	*Metric Tons.*
1898	986,158	*1,001,982*
1899	920,659	*935,432*
1900	1,005,185	*1,021,315*
1901 . . .	1,102,039	*1,119,672*
1902	1,040,206	*1,056,899*
1903	823,184	*836,394*
Average	*979,572*	*995,282*

TABLE 45.—*Provincial Production of Salt during the years 1898 to 1903.*

	1898.	1899.	1900.	1901.	1902.	1903.	*Averages.*
	Statute Tons.	Statute Tons.	Statute Tons.	Statute Tons.	Statute Tons.	Statute Tons.	*Statute Tons.*
Aden . . .	41,217	41,181	49,763	87,800	58,953	71,656	*54,428*
Bengal . . .	...	...	174	112	44	94	(a) *106*
Bombay . .	343,569	368,072	460,262	323,909	381,611	267,619	*357,507*
Burma . . .	18,223	23,240	20,835	21,500	20,013	26,174	*21,664*
Gwalior State .	456	333	352	491	485	489	*434*
Madras . . .	251,875	268,962	322,244	239,544	358,450	244,923	*297,666*
Northern India .	359,790	248,574	190,532	405,068	269,177	270,068	*290,535*
Sind . . .	12,245	11,478	10,786	11,415	10,426	13,817	*11,695*
TOTAL Statute Tons.	1,027,375	961,840	1,054,948	1,189,839	1,099,159	894,840	1,038,000
Metric Tons . .	*1,043,862*	*977,269*	*1,071,877*	*1,208,033*	*1,116,797*	*900,200*	*1,054,665*

(a) Average of 4 years.

Provincial contributions to the total production.

Of the provinces contributing to this amount, Bombay, with an average annual production of 357,507 tons, and Madras, with an average of 297,666 tons, between them contributed almost exactly two-thirds of the total. Of the salt produced in Bombay, about 78 per cent. was obtained from sea-water, the rest being manufactured from sub-soil brine at Kharaghora and Udu on the border of the lesser Rann of Cutch, and possibly derived from infiltrated sea-water. The Madras salt is practically all made from sea water, a very small quantity of spontaneous salt being collected at Pandraka in the Masulipatam sub-division.

The chief manufacture of salt in Burma takes place also along the sea-coast, but sub-soil brine is evaporated at various places in Upper Burma, notably in the Lower Chindwin, Sagaing, Shwebo, Myingyan, and Yamethin districts, and in smaller quantities in Minbu and Meiktila, as well as at Mawhkeo in the Hsipaw State. During the past six years the average annual production of this salt in Burma has been 3,432 tons.

In Sind 88 per cent. of the salt raised during the years 1898 to 1903 was obtained from sea-water, and 12 per cent. from the Saran and Dilyar deposits on the edge of the great desert.

From the point of view of the geologist and mineralogist, the last two groups of occurrences, namely, sub-soil salt and rock-salt, are naturally of more interest than the first, though from the financial point of view the salt from sea-water, being the predominating fraction, is the most important source of revenue.

Sub-soil and internal lake brine.

The second form of occurrence is characteristic of areas in which evaporation of rain-water is excessive compared to run-off, and the salt recovered in these areas is that merely arrested on its journey to the sea, where, in the same way, it is concentrated by evaporation of the water. The most prominent of such areas is the desert-belt of Rajputana including the salt-lakes of Sambhar, Didwana, Falodi, Lonkara-sur and Kachor-Rewassa, with a brine-impregnated sub-soil along the whole valley of the Luni, as well as the country to the west in Sind, around the Rann of Cutch and the delta of the Indus. To the north of the Rajputana country sub-soil brine is raised and evaporated for salt in a cluster of villages in the Sultanpur mahal, south-west of Delhi. Other places occur in parts of the United Provinces and in Berar, where large

quantities of salt were formerly obtained from sub-soil brine in the alluvium of the Purna River. In Gwalior State salt is regularly manufactured from sub-soil brine, the average annual production during the years 1898 to 1903 having been 434 tons. In Behar a small quantity of salt is separated in the manufacture of saltpetre. The returns for the past four years for Bengal, with an average of 106 tons per annum, quoted in table 45, refer to salt made in this way.

Sambhar Lake.

The most important source of salt of this group is the Sambhar Lake in Rajputana. Recent investigations have shown that Sambhar is a silt-filled depression in the Aravalli schists and gneisses; in which a body of mud and sand, with kankar and gypsum (some 75 feet thick in what appears to be about the centre of the depression) includes from 2 to 12 per cent. of sodic chloride, with smaller quantities of sodic sulphate, sodic carbonate, and potassic sulphate. Every year the water brought in by the rivers, which are in flood during the monsoon, forms a lake some 60 square miles in area and 2 to 3 feet deep. The water, which is fresh when it first comes in, takes up salt from the accumulated stocks in the silt and forms a strong brine, which is partly led into prepared enclosures (*kyars*) for the separation of salt by solar evaporation, partly isolated by temporary reservoirs constructed to cut off bodies of the lake-water in anticipation of the recession towards the centre during evaporation, and partly forms a thin crust of white glistening salt on the bed of the lake, where it is allowed to remain until the arrival of the next monsoon and the usual annual flooding of the lake.

Production and prospects of Sambhar.

During the past six years the average annual removal of salt from the Sambhar brine has been 135,051 tons, which is 13·8 per cent. of the average annual production for India during the same period. Since the lake came under the direct control of Government in 1871 the salt removed has amounted to about 4 million tons. During the past few years the quality of Sambhar salt is said to have depreciated, and it has been suspected that the large quantities which have been removed have at last made an impression on the great stores of salt which must have accumulated in the lake silt, appreciably raising the proportion of the associated compounds, sodium sulphate, sodium carbonate, and potassium sulphate. An investigation is now being made with a view to forming an estimate of the total and relative amounts of these salts present in the lake mud, and of obtaining a forecast of the effects of

fractional solution and crystallization under the existing system of manufacture.

Distribution of Sambhar salt.

The chief fraction of the output of Sambhar is consumed in the United Provinces, but small quantities reach as far even as Behar against the competition of foreign salt imported through Calcutta. The following table shows the average annual distribution of Sambhar salt during the years 1897-98 to 1902-03 :—

United Provinces	91,443	tons, or	68·3	per cent. of total.
Rajputana	20,371	„ „	15·3	„ „
Central India	11,713	„ „	8·8	„ „
Punjab and North-West Frontier Province	9,109	„ „	6·8	„ „
Central Provinces	716	„ „	0·5	„ „
Behar	175	„ „	0·1	„ „
Sind (in 1902-03 only)	294	„ „	0·2	„ „

Distribution of Didwana and Pachbadra salt.

The salt being manufactured at Didwana is practically all consumed in Rajputana and the adjoining districts of the Punjab. During the years 1897-98 to 1902-03 the average annual amount, 10,502 tons, disposed of from this source was divided into 8,123 tons for the Punjab and 2,379 tons for Rajputana. Pachbadra salt, of which only small lots entered the Punjab, had an average distribution as follows during the period under review :—

Average Distribution of Pachbadra Salt during the years 1897-98 to 1902-03.

United Provinces	15,345	tons, or	45·6	per cent. of average total
Rajputana	9,216	„ „	27·3	„ „ „
Central India	5,553	„ „	16·5	„ „ „
Central Provinces	3,562	„ „	10·6	„ „ „
TOTAL	33,677	tons.		

Production of rock-salt.

The production of rock-salt in the Punjab, North-West Frontier Province and Mandi State is shown in table 46, from which it will be seen that, of the average annual output of 109,540 tons, 89,023 tons, or 81·2 per cent., came from the Salt Range mines, whilst 14·5 and 4·3 per cent. respectively came from Kohat and Mandi.

TABLE 46.—*Production of Rock-Salt during the years 1898 to 1903.*

YEAR.	Salt Range, Punjab.	Kohat North-West Frontier.	Mandi State.	TOTAL.	Percentage of total salt production of India.
	Tons.	Tons.	Tons.	Tons.	
1898	91,117	17,225	4,754	113,094	11·4
1899	91,488	17,693	4,621	113,802	12·3
1900	81,534	14,900	4,122	100,556	10·0
1901	91,816	14,965	4,845	111,626	10·1
1902 . . .	87,426	14,674	5,152	107,252	10·3
1903	90,736	15,598	4,554	110,888	13·5
Average . . .	*89,023*	*15,842*	*4,675*	109,540	*11·2*
Per cent. of Average Total .	81·2	14·5	4·3	100·0	

The Salt Range deposits.

The chief deposits of rock-salt are in the so-called Salt Range of the Punjab, where the seams of salt and included marl partings have, where worked in the Mayo mines at Khewra, an aggregate thickness of 550 feet, of which five seams of pure salt make up 275 feet, the rest, known as *kalar*, being too earthy and impure to be marketable. These beds occur in a formation lying directly underneath beds of Lower Cambrian age, but it is suspected that they may be of Lower Tertiary age, like the other salt deposits of this part of India, and that they have arrived in their present apparently anomalous position by an overthrust of the older fossiliferous beds.

Mining for rock-salt is carried on in the Mayo mines, Jhelum district, the Warcha mines in the Shahpur district, and across the Indus at Kalabagh. The rock-salt in this area varies from white to brick-red in colour and thus differs in colour from that of the Kohat area.

The Mayo mines.

The most important of the mines in the Salt Range are the Mayo mines near Khewra (32° 39′; 73° 3′). In this area salt-quarrying was practised for an unknown period before the time of Akbar, and was continued in a primitive fashion

until it came under the control of the British Government with the occupation of the Punjab in 1849. In 1872 the system of mining was reorganized, and the work now in operation was planned out by Dr. H. Warth, late Deputy Superintendent, Geological Survey of India.[1]

The rock-salt being raised in the Mayo mines has, on account of its purity, a wide distribution. A recent analysis of one of the seams gave the following results:—

Sodium chloride	98·86
Sodium sulphate	0·57
Sodium carbonate	trace
Magnesium chloride	nil
Moisture	0·08
	99·51

The Warcha mine. In the Warcha mine, Shahpur district, the seam of rock-salt being worked is 20 feet thick, with a one-foot parting of marl, dipping 30° to the N. N. W.

Kalabagh quarries. About two miles E.N.E. of Kalabagh on the Indus, rock-salt is worked in open quarries on the east slope of Sandagar hill.

Distribution of Salt Range salt. The rock-salt raised in the *cis*-Indus mines and Kalabagh quarries is principally consumed in the Punjab and North-West Frontier Province. During the past six years the average annual sales in these provinces amounted to 70,964 tons, or 82·3 per cent. of the total. In the same period the rock-salt sent to the United Provinces averaged 10,049 tons a year, or 11·3 per cent., whilst as much as 5·7 per cent. of the total sales, or an annual average of 4,933 tons, reached as far as Behar, and small consignments of about 10 tons a year were despatched to Lower Bengal. The average annual amount of 580 tons which entered Sind formed 0·7 per cent. of the sales for the years 1897-98 to 1902-03.

Kohat quarries. The Kohat salt is grey in colour with transparent patches. It is worked in open quarries, and the masses exposed may be regarded as practically inexhaustible at the present rate of output. In the anticlinal at Bahadur Khel, where the salt is seen to be at the base of Tertiary system, the beds can be

[1] For detailed description, see "Report on the Inspection of the Mayo Salt Mine," by J. Grundy, 1898, pp. 13-15.

traced for a distance of about eight miles, with an exposed thickness of over 1,000 feet.

Mandi quarries.

In Mandi State, rock-salt is worked in open quarries near the faulted junction of the Tertiary and the older unfossiliferous rocks at Guma and Drang. The Mandi salt is of a dirty plum-colour, containing earthy impurities which bring down the available sodic chloride to 60 or 70 per cent.

Imports and origin of Foreign salt.

With low freight-rates from Europe, large quantities of salt are imported, especially into Bengal and Burma, against the competition of the domestic produce. The salt imported during the six years under review averaged 433,754 tons per annum, of which 56·1 per cent., as shown by table 47, came from the United Kingdom, the remaining supplies being obtained, in order of average quantity, from Germany, Aden, Arabia, Egypt, and Persia. The average annual value of the salt imported during the six years was £456,263.

TABLE 47.—*Origin of the Salt imported during the years 1897-98 to 1902-03.*

Imported from	Average annual quantity imported.	Per cent. of total.
	Tons.	
United Kingdom	243,216	56·1
Germany	56,928	13·1
Aden	49,350	11·4
Arabia	42,887	9·9
Egypt	28,377	6·5
Persia	12,441	2·9
Other Countries	555	0·1
Average Total for the years 1897-98—1902-03 .	**433,754**	100·0

The amounts taken by the different provinces maintained a fairly

constant ratio throughout the period, with the following yearly averages:—

Imported to Bengal	. . . . .	389,376 tons.
„ „ Burma	. . . . .	43,978 „
„ „ Bombay	. . . . .	260 „
„ „ Madras	. . . . .	91 „
„ „ Sind	. . . . .	49 „
	TOTAL .	433,754 „

Of the average annual amount imported, therefore, 89·8 per cent. entered India through Bengal. The distribution of foreign salt in India in competition with the chief sources of production is reviewed in the annual reports of the various Salt Departments.

Trans-Frontier Imports and Exports.

Small quantities of salt are also imported across the land frontier, coming in with borax mainly from Tibet. During the years 1898 to 1903 these imports averaged 1,476 tons annually, of which 1,416 tons came from Tibet. At the same time considerable quantities of Indian salt were sent across the frontier. The average annual export in this way during the six years under review amounted to 41,170 tons. The principal fractions went to Nepal (12,943 tons) and into Kashmir (11,234 tons).

Saltpetre.

Conditions essential for the formation of saltpetre.

For the formation of saltpetre in a soil the necessary conditions are (1) supplies of nitrogenous organic matter, (2) climatic conditions favourable to the growth and action of Winogradsky's so-called nitroso and nitro bacteria, converting urea and ammonia successively into nitrous and nitric acids, (3) the presence of potash, and (4) meteorological conditions suitable for the efflorescence of the potassium nitrate at the surface. An ideal combination of these necessary circumstances has made the Behar section of the Gangetic plain famous for its production of saltpetre.

In this part of India we have a population of over 500 per square mile, mainly agricultural in occupation, and thus accompanied by a high proportion of domestic animals, supplying an abundance of organic nitrogen. With a mean temperature of 78° F., confined to an annual range of 68°, and for a large part of the year, when the air has a

humidity of over 80 per cent., with a diurnal range not exceeding 8° above or below 84° F., the conditions are unusually favourable for the growth of the so-called "nitrifying" bacteria.

With a population largely using wood and cow-dung for fuel, the soil around villages naturally would be well stocked with potash; and finally, with a period of continuous surface desiccation following a small rainfall, the sub-soil water, brought to the surface by capillary action in the soil, leaves an efflorescence of salts, in which, not surprisingly, potassium nitrate is conspicuous. Under these conditions Behar has for many years yielded some 20,000 tons of saltpetre a year.

System of manufacture.

The system of manufacture has been very frequently described in detail,[1] and consists essentially in dissolving out the mixed salts contained in soil around villages, and effecting a first rough separation of the two most prominent salts—sodium chloride and potassium nitrate—by fractional crystallization. The impure sodium chloride is consumed locally, whilst the saltpetre is sent to refineries for further purification before export.

Production and export.

The returns for production are so manifestly imperfect, being considerably below the amounts of export, that the export figures must be taken as the only index, though still an imperfect one, to the extent of the manufacture. The export figures for the past six years are given in table 48, showing an average annual export of 382,353 cwts., valued at £262,592.

Variations in exports.

There is no definite directional change indicated by these figures, but a comparison with the returns for the past 20 years shows that there has been only a slight reduction in the amount of exported saltpetre, in spite of the discovery elsewhere of large deposits of sodic nitrate, now being largely consumed in America, of variations in tariff, and of wholesale changes in the substances used for manures and for the manufacture of explosives. For the six years 1878—1883 the average quantity of saltpetre exported amounted to 405,568 cwts. a year, whilst for a similar period ten years later, namely, 1888 to 1893, the average annual exports were 389,989 cwts. The highest values, ranging from about £600,000 to nearly £900,000 a year, occurred at the time of the American Civil War from 1860 to 1864, but saltpetre was then an essential constituent of explosives and India had almost a monopoly of supplies.

[1] G. Watt, Dictionary of the Economic Products of India, vol. VI, part II, s. 686, p. 433, and literature quoted.

TABLE 48.—*Total Exports of Saltpetre during the years 1897-98 to 1902-03.(a)*

YEAR.	QUANTITY.		Value.	Value per cwt.
	Cwts.	*Metric tons.*		
			£	Shillings.
1897-98	417,788	*21,224*	265,831	12·73
1898-99	365,256	*18,555*	232,896	12·75
1899-00	397,402	*20,189*	256,210	15·16
1900-01	348,636	*17,711*	294,249	16·88
1901-02	354,412	*18,005*	237,880	13·42
1902-03	410,626	*20,861*	288,487	14·05
Average .	*382,353*	*19,424*	*262,592*	*13·73*

(*a*) Includes exports across the frontier which averaged 380 cwts., due mainly to 2,233 cwts. sent into Kashmir in 1900. The saltpetre sent across the frontier seldom exceeds a ton per annum.

Distribution of exported saltpetre.

There have been various changes amongst the consumers of small quantities, amounting altogether to about 20 per cent. of the total, but the quantities sent annually to the three larger markets, United Kingdom, United States, and Hong Kong, amounting to 80 per cent. of the total, have remained fairly constant.

Provincial shares in the exports.

Calcutta is still, as it always has been, the chief port through which saltpetre leaves India, the exports through Calcutta, during the pericd under review, having amounted to 98·5 per cent. of the total. Of the remaining small amount exported, 1·2 per cent. left *viâ* Karachi. The average annual exports from the different provinces have been as follows during the years 1897-98 to 1902-03:—

Bengal	376,254	cwts.
Bombay	930	„
Madras	61	„
Sind	4,728	„
TOTAL .	381,973	„

The Calcutta supply is obtained mainly from Behar, as shown in table 50, which has been compiled from returns published each year by the Commissioner of Northern India Salt Revenue.

TABLE 49.—*Average Distribution of Saltpetre exported by Sea during the years 1897-98 to 1902-03.*

EXPORTED TO	Average annual quantity.	*Per cent. of average total.*
	Cwts.	
United Kingdom	117,126	30·7
Hong Kong	98,320	25·7
United States	91,790	24·0
Mauritius	24,070	6·3
France	22,752	6·0
Straits Settlements	10,012	2·6
Ceylon	7,569	2·0
Japan	5,227	1·4
Other Countries	5,107	1·3
Average Total for the years 1897-98—1902-03	**381,973**	100·0

TABLE 50.—*Average Annual Imports of Saltpetre into Calcutta for the years 1897-98 to 1902-03.*

OBTAINED FROM	Average annual quantity.	*Per cent. of average total.*
	Cwts.	
Behar	230,120	59·1
United Provinces	113,680	29·2
Punjab	44,300	11·3
Rajputana and Central India	1,540	·4
Lower Bengal	100	...
Average Total	**389,740**	

Trans-Frontier imports.

Only very small quantities of saltpetre for chemical and medicinal purposes are imported into India by sea, but a considerable quantity comes from Nepal. During the past six years the imports from Nepal have averaged 9,417 cwts. with considerable yearly variations, as shown below :—

Saltpetre imported from Nepal.

1897-98	9,308	cwts.
1898-99	12,836	„
1899-00	15,655	„
1900-01	4,590	„
1901-02	11,352	„
1902-03	2,758	„
Annual Average	*9,417*	„

As the total annual imports of saltpetre averaged only 9,430 cwts. during the six years under review, the contribution from Nepal was the only one of importance. The annual values returned for the total imports give an average of £5,816, or of 12·34 shillings per cwt.

Tin.

Unworked occurrences.

Tin has a wider distribution than is generally recognised, and its minerals are often overlooked through the difficulty in distinguishing them from other heavy minerals. Isolated crystals of cassiterite have been found recently in pegmatites associated with gadolinite in the Palanpur State,[1] whilst in the Hazaribagh district of Chota Nagpur instances have been recorded of the accidental production of tin from river sands by the native iron smelters, in addition to the recorded occurrences of ores *in situ*. The principal deposit, which has either been wrongly described or has received less attention than it deserves, occurs in the Palganj estate near the Barakar river.

Worked deposits.

The only persistent attempts made to work tin have been in Burma, where cassiterite is obtained by washing river gravels in the Bawlake State, Karenni, Southern Shan States, and in the Tavoy and Mergui districts of South Burma. The work done on these deposits hitherto has been, however, on a

[1] Rec. Geol. Surv. Ind., xxxi, 1904, 43.

smaller scale than might be expected from the favourable reports which have been made as to their extent and richness. Table 51 shows the amounts of tin-ore raised during the years under review in Tavoy and Mergui, but the returns are probably approximate only, and no returns are available for Upper Burma. The average for the period has been 1,645 cwts. (82·5 tons) valued at £6,876.

TABLE 51.—*Production of Tin-ore in South Burma.*

YEAR.	Tavoy.	Mergui.	TOTAL.	
			Quantity.	Value.
	Cwts	Cwts.	Cwts.	£
1898	...	780	780	2,553
1899	14	1,408	1,422	7,900
1900	19	2,059	2,078	8,534
1901	22½	1,372	1,395	7,773
1902	25	1,970	1,995	5,340
1903	34	2,164	2,198	9,153
Average .	*19*	*1,626*	*1,645*	*6,876*

Exports of block tin.

The metal is exported mainly in the form of block tin, almost all of it going to the Straits Settlements. This, during the years 1897-98 to 1902-03, averaged 661 cwts. a year, as shown in table 52.

Imports of block tin.

The tin exported from Burma is a small quantity compared to the requirements of the country. Table 53 shows the amounts of foreign unwrought block tin which have been consumed in India during the period under review, and in addition to these quantities, smaller quantities of tin-plates are imported. By far the largest quantity of block tin imported into India comes from the Straits Settlements. Out of the average total of 26,867 cwts., the quantity coming from the Straits averaged 25,407 cwts. per annum. A curious feature connected with the imports is the fact that the quantities of foreign tin imported have not increased since statistics of weight were first recorded in 1875-76. In that year the tin

imported was reported to amount to 36,159 cwts., of which 31,479 cwts. came from the Straits.

TABLE 52.—*Exports of Burmese Block Tin for the years 1897-98 to 1902-03.*

YEAR.	Quantity.	Value.
	Cwts.	£
1897-98	905	2,816
1898-99	810	2,898
1899-00	757	4,613
1900-01	534	3,08
1901-02	455	2,574
1902-03	502	2,881
Average	*661*	*3,144*

TABLE 53.—*Consumption of Foreign Block Tin in India.*

YEAR.	IMPORTS.		Re-exports.	Consumption.
	Quantity.	Value.		
	Cwts.	£	Cwts.	Cwts.
1897-98	38,483	146,554	1,609	36,874
1898-99	29,099	110,667	1,396	27,703
1899-00	17,292	91,525	2,473	14,819
1900-01	22,591	146.135	2,624	19,967
1901-02	25,907	156,212	1,853	24,054
1902-03	27,830	169,731	1,495	26,335
Average	*26,867*	*136,804*	*1,908*	*24,959*

Prospects of tin-mining.

As regards the prospects of tin-mining in Burma, it may be worth notice that the country in which the ore occurs lies in a belt connecting Yunnan, the south-west province of China, in which tin-mining is said to support a large population,[1] and the well known tin-ore deposits of the Straits Settlements to the south, from which, in 1903, 54 per cent. of the World's supply of tin was obtained.

At the same time, it should be kept in mind that the tin-ore of the Straits has been obtained entirely from alluvial deposits, and that the ore found in lodes has always turned out to be too poor to work. The rapid rate of rock denudation in the wet zone of the tropics is responsible for the fact that rich alluvial deposits may accompany poor lodes, and consequently the occurrence of tin-ore in the sands and gravels of Burma does not warrant the hope that workable lodes will be found before the placer deposits are exhausted. That rich placer deposits exist of sufficient magnitude in Burma also does not necessarily follow from the fact that there is a continuity in the solid geology; the existence of a placer deposit is but a temporary accident in the geological history of a country, and each one must be gauged for itself.

[1] A. Leclère. Exploration géologique des Provinces chinoises voisines du Tonkin. *C. R., 29eme Session, Assoc. Fr.*, 1900, ii, 916-926. Abs. *Trans. Inst. Mining Engineers*, XXII, 1901-02, 715.

IV.—MINERALS OF GROUP II.

Alum and Aluminium-ore.

THE separation of the sulphate of alumina from decomposed pyritous shales, and the preparation of the double sulphate of alumina and potash, by the introduction of nitre or wood-ashes, was formerly an important industry in a few places, and, on a smaller scale, was practised at numerous places in India. But the importation of cheap alum, principally from the United Kingdom, and its wide distribution by the gradually extending network of railways, have now nearly killed the native industry. Table 54 shows that during the past six years the consumption of foreign alum in India has averaged 66,086 cwts.

TABLE 54.—*Consumption of Foreign Alum in India.*

YEAR.	IMPORTS.		Re-exports.	Consumption of foreign alum.
	Quantity.	Value.		
	Cwts.	£	Cwts.	Cwts.
1897-98 . . .	103,307	30,928	3,050	**100,257**
1898-99 . . .	70,999	18,837	3,320	**67,679**
1899-00	65,953	17,404	4,037	**61,916**
1900-01 . . .	64,528	18,398	3,137	**61,391**
1901-02	49,914	15,137	2,240	**47,674**
1902-03	61,081	18,789	3,478	**57,603**
Average .	*69,296*	*19,015*	*3,210*	**66,086**

No returns are available to show the amount of production in India. Near Kalabagh, on the Indus, considerable quantities of a pyritous shale are extracted for this purpose, but the mining is carried on in an irregular, fitful way, and the returns are probably mere rough

estimates. In 1898 the output was reported to amount to 750 tons, valued at £3,150, but no returns are available for 1899 and 1903. In 1901 and 1902 the production was reported to be 98 and 112½ tons respectively.

Bauxite.

India possesses a possible asset of great value in the deposits of laterite which cover considerable areas in the Peninsula and Burma. On account of their commonly rusty colour, and on account of the fact that locally the native smelters, content with a poor ore, have employed laterite as a source of iron, the only chemical work done on laterite was formerly devoted to a determination of its content in iron. It has only recently been ascertained that many of the deposits contain large quantities of alumina, and are in all essential respects identical with the substance known as bauxite, which is now the chief source of aluminium. It is a curious coincidence that for a long time the original bauxite of Les Baux was, like laterite, first worked without success as a source of iron.

It is difficult at present to fully estimate the value of this discovery, as a deposit of laterite, which would ordinarily be regarded as small and of little consequence, contains enough alumina in some of the instances examined to completely swamp the market of bauxite, of which the World's total production is at present little more than 110,000 tons a year. Without any disturbance of present prices, the aluminous laterites would hardly pay, at the ordinary rate for first class bauxites of 21 to 22 shillings a ton, to mine for export to Europe and America, and they must consequently be utilized for the extraction of alumina on the spot, either for export as such, or for the manufacture of aluminium in the country. To prepare the alumina from the bauxite (or laterite) would, according to the most recent processes, require the use of caustic soda, which is not at present made in the country. But one of the latest successful processes for the manufacture of caustic soda involves the separation of chlorine (from which bleaching powder is prepared) by the electrolytic decomposition of dilute brine, and as both caustic soda and bleaching powder are now largely imported for use in paper-making, there would be a market for both, apart from the requirements of alumina manufacture.

Amber.

The returns for amber show the irregularities which might be expected of an industry conducted in a casual fashion by the

half-civilized inhabitants of an unadministered area. The following table (table 55) shows the estimated production for the six years under review :—

TABLE 55.—*Production of Amber in the Myitkyina District, Upper Burma.*

YEAR.	Quantity.	Value.
	Cwts.	£
1898	114	1,061
1899	20	151
1900	9	103
1901	97	(*a*) 11
1902	30	432
1903	37	414
Average	*51*	*362*

(*a*) Poor qualities only raised for medicine in 1901.

Occurrence.

The Burmese diggings for amber are situated in the Hukong valley in the Nangotaimaw hills near Lalaung village at about lat. 26° 10′ and long. 96°. The substance is found in clays of probably miocene age, and fragments of amber have been similarly found in association with beds of this age in other parts of Burma, for example, at Mantha in the Shwebo district, and on the oil-field of Yenangyat in the Pakokku district. Most of the material is brought from the Hukong valley in Upper Burma to Mandalay, where beads for rosaries, *nadaungs* (ear-cylinders) and other trinkets for personal ornament are made from the transparent varieties.

Chemical and physical properties.

The amber of Burma differs in chemical and physical characters from previously known varieties, and the name burmite has been consequently suggested for it as a specific distinction.[1] The well known amber of Eastern Prussia contains from 2½ to 6 per cent. of succinic acid, and

[1] O. Helm, *Records, Geol. Surv. Ind.*, xxv, 180 (1892), and xxvi, 61 (1893).

is consequently known to the mineralogist as succinite, but the Burmese amber contains no succinic acid, though the products of its dry distillation include formic acid and pyrogallol. Its ultimate chemical composition has been determined to be as follows:—

Carbon	80·05
Hydrogen	11·50
Oxygen	8·43
Sulphur	0·02
	100·00

The specific gravity of burmite varies between 1·030 and 1·095. It is distinguished from many other amber-like resins by its superior hardness and greater toughness, which render it fit for carving and turning. It possesses a peculiar fluorescence, like that which distinguishes the Sicilian variety simetite.

Apart from the occurrence of a large percentage of discoloured and opaque pieces, many of the large fragments obtained are damaged by cracks filled in with calcite; but otherwise there appears to be a large quantity of material which might be put on the market with profit. At present it is said to be unable to withstand the competition of imported Prussian amber, even in the Mandalay bazar, and the market has to a certain extent been depressed by cheaper foreign material and by an artificial substance re-made from amber chips.

Antimony.

Prospecting operations for antimony-ores, amongst which stibnite is the most prominent, have been carried on in South Burma, and in Lahoul, where a large deposit occurs near the Shigri glacier. The latter occurrence is included in a mining lease recently granted, and an attempt is about to be made to mine the ore.

Much of the material sold in the bazars under the name *surma* includes galena as well as antimony, and the word has the same wide significance which the term "black lead" once possessed.

Arsenic.

Details with regard to the production and use of Indian arsenic are not available, but there has been a considerable trade in both Indian and foreign arsenic, presumably in the form of the white oxide.

Table 56 shows the extent of this trade for the period under review, but does not include the trade in orpiment, which is shown separately.

TABLE 56.—*Average Annual Exports and Imports of Arsenic for the years 1897-98 to 1902-03.*

—	Quantity.	Value.
	Cwts.	
Exports of Indian Arsenic—		
To Straits Settlements	308	
„ Other Countries	26	
TOTAL .	334	£ 525
Imports of Foreign Arsenic—		
From the United Kingdom	421	
„ „ Germany	829	
„ „ China	909	
„ „ Straits Settlements . . .	99	
„ „ Other Countries	88	
TOTAL .	2,346	£ 3,110
Re-export of Foreign Arsenic	111	

Orpiment.

Orpiment, the yellow sulphide of arsenic, is largely imported into Burma from Western China for use mainly as a pigment. During the six years 1897-98 to 1902-03, the average annual imports across this frontier amounted to 9,551 cwts., at an estimated value of £11,470, or 24 shillings per cwt. The last three years have shown a decided increase in the trade, with, however, an average reduction in the price per cwt. (see table 57).

namely, an average of 214 cwts., it is seen that the consumption in India has averaged 17,655 cwts. per annum during the years 1897-98 to 1902-03.

TABLE 59.—*Imports of Borax by Land during the years 1897-98 to 1902-03.*

Year.	Quantity.	Value.	Value per cwt.
	Cwts.	£	Shillings.
1897-98	15,273	12,097	15·84
1898-99	16,564	13,053	15·76
1899-00	20,315	16,424	16·17
1900-01	18,621	15,065	16·18
1901-02	31,085	24,096	15·50
1902-03	29,874	23,482	15·72
Average	*21,955*	*17,369*	*15·82*

Of the amounts brought across the frontier, and shown in table 59 to have an annual average of 21,955 cwts., 1,117 cwts., or 5·1 per cent., came from Ladakh, whilst 20,831 cwts., or 94·9 per cent., came from Chinese Tibet.

The borax obtained in the Puga valley of Ladakh, Kashmir, is deposited from hot springs, associated with sulphur deposits, which probably represent the final phase of declining volcanic action. The material collected in Tibet is obtained from salt lakes, which have possibly obtained their borax in a similar way from hypogene sources. In other parts of the World, as in California, Argentina, Bolivia, and Chile, deposits of calcium borate, colemanite, are worked for their boracic acid, besides the borax of salt lakes and marsh deposits. In Italy borax is obtained from volcanic fumaroles.

Building-Stone.

If the extent of the use of building materials could be expressed by any recognised standard, it would form one of the best guides to the

in the Himalayan passes, herds of goats and sheep coming down in the spring from Tibet, each carrying two small bags of borax or salt to be bartered for Indian and foreign stores.

TABLE 58.—*Exports of Borax by Sea from India during the years 1897-98 to 1902-03.*

Year.	Quantity.		Value.	Value per cwt.
	Cwts.	*Metric tons.*		
			£	Shillings.
1897-98	3,624	*184*	4,339	23·95
1898-99	4,999	*254*	6,429	25·72
1899-00	4,405	*224*	6,304	28·62
1900-01	3,190	*162*	5,020	31·47
1901-02	5,666	*288*	8,594	30·34
1902-03	5,002	*224*	7,534	30·12
Average	*4,481*	*228*	*6,370*	*28·43*

In addition to the borax sent by sea to foreign countries, small quantities cross the frontier into Nepal, Kashmir, and Kalat. During the six years, 1897-98 to 1902-03, these trans-frontier exports of borax have averaged 23 cwts. a year, with an average total value of Rs. 377 (£25) or R.s 16·4 (22*s.*) per cwt. The export trade has very seriously declined. Twenty years ago the borax sent out of India amounted to over 16,000 cwts. a year, valued at £24,000. At that time the principal part of the material exported went to the United Kingdom (14,134 cwts. in 1883-84), but with the discovery of large deposits of calcium borate in America the demand for borax from India ceased, and now the only large customers are in the Straits Settlements and China, the latter having taken 3,827 cwts., and the former 468 cwts., of the average annual total of 4,481 cwts. exported.

The amount of borax imported into India across the frontier has averaged (as shown in table 59) 21,955 cwts., of the value of £17,369; adding to this the small quantity of refined material imported by sea,

namely, an average of 214 cwts., it is seen that the consumption in India has averaged 17,655 cwts. per annum during the years 1897-98 to 1902-03.

TABLE 59.—*Imports of Borax by Land during the years 1897-98 to 1902-03.*

Year.	Quantity.	Value.	Value per cwt.
	Cwts.	£	Shillings.
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1898-99	16,564	13,053	15·76
1899-00	20,315	16,424	16·17
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Building-Stone.

If the extent of the use of building materials could be expressed by any recognised standard, it would form one of the best guides to the

industrial development of a country. The attempt made to obtain returns of building-stone, road-metal and clays used in India was abandoned when it was shown in 1899 that the returns could not possibly rank in value much above mere guesses. The same remark might possibly apply to any other country, where figures are regularly reported, though they are of little value for comparative purposes on account of the varying systems of making estimates.

In the United Kingdom, where land is generally sufficiently valuable to cause an increase of depth in quarrying to be less expensive than horizontal extension, a large proportion of the quarries come under the control of the Mines Acts, and regular returns for production are consequently available; but in India there are only a few quarries of more than 20 feet in depth, and the returns from them represent an unimportant fraction of the total amount of material which is being raised all over the country for public works of all kinds. For the present, therefore, we must be content with a general statement to represent the changes from one period to another.

In the absence of statistics, it is difficult to express shortly the trade in material so widespread as common building-stone. There are, however, a few features which are specially developed in, if not peculiar to, India. In the southern part of the Peninsula, various igneous rocks—the charnockite series near Madras, and the gneissose granites of North Arcot and Mysore—are largely used; in the centre, slates and limestones from the Cuddapah series, and basalt from the Deccan trap-flows are largely used. In Central India, Central and United Provinces, the great Vindhyan system provides incomparable sandstones and limestones, whilst in Bengal the Gondwana sandstones are used on, and within easy distance of, the coal-fields.

The abundant development of concretionary carbonate of lime in the great alluvial plains, and the extensive development of laterite on the Peninsula and in Burma are dependent, in their more pronounced forms, on conditions peculiar to tropical climates, and these two substances, the so-called kankar and laterite, are about the most valuable assets in building material possessed by the country.

The three great physical divisions of India, being the result of three distinct geological histories, show general contrasts in the materials available for simple as well as ornamental architecture. In the great alluvial plains, buildings of importance are naturally most often made of brick, but the margins on all sides admit of a certain inward

diffusion of stone, which has been extended by increased facilities for transport. In this respect it is interesting to see that at last the monotony of brick buildings in Calcutta is being relieved by the introduction of the Vindhyan sandstones of Mirzapur, and the calcareous freestones and buff traps brought from the west coast. But the use of Italian marble, mainly for floorings, and, in a smaller way, the introduction of polished granite columns and blocks from Aberdeen and Peterhead, have been persisted in mainly because these materials, which are no better than, and possibly on the whole inferior to, those of Indian origin, are placed on the market in a manner suitable to the immediate requirements of the builder and architect. It is thus not because of the dearth of natural resources, but it is on account of the want of enterprise, that Indian ornamental building stone is less used in the chief cities.

During the six years under review the stone and marble imported from foreign countries into India had an average annual value of £19,848, and of this amount the value of marble from Italy was £10,221, or 51·5 per cent. of the average annual total. It is naturally surprising to find that a country which owes its reputation for architectural monuments as much to the fact that it possesses an unlimited supply of ornamental building stone as to the genius of its people, is dependent on foreign supplies to the extent indicated by these import returns. It can hardly be an accident that each dynasty, which has existed in India since the wonderful Buddhist topes of Sanchi and Bhahrut were erected, has been marked by the erection of great monuments in stone, and there can be little doubt that the abundance of suitable material has been an important contributory cause in the growth of India's reputation for architecture.

A recent development of importance has occurred in quarrying the nummulitic limestones of the Khasia and Jaintia hills, partly for use in the manufacture of lime or for use as simple limestone, and partly for the manufacture of cement near Calcutta. In 1898 the amount of limestone quarried in this district was estimated at 61,105 tons, but considerable fluctuations were shown in subsequent years with a general improvement to 88,675 tons in 1903.

For some of the quarries in Lower Vindhyan limestone near Katni, which have come under the control of the Indian Mines Act, returns are available since 1901, when the quantity raised was 28,000 tons, followed by 30,091 tons in 1902, and 35,238 tons in 1903. A limestone

of Upper Vindhyan age is being worked near Sutna by a joint stock company, but much of the material is carried by rail a distance of 530 miles to the Barakar Iron Works, where it is used as a flux in the blast furnaces.

Chromite.

Chromite is known to occur with the peridotites of the Chalk hills near Salem, in the Andamans, and in Baluchistan. Attempts were made long ago to work the deposits near Salem, but nothing has been done since. In Baluchistan the ore occurring in the Pishin and Zhob districts is being opened up for export, the output for the first year of work, 1903, being returned as 284 tons. Larger quantities are now being raised, the amount for the first half of 1904 being 1,816 tons.

Clays.

No statistics approaching any degree of completeness are obtainable to show the extent of the undoubtedly great industrial value of the clays in India. They include the common clays used all over the country for the manufacture of bricks, tiles and the cheaper forms of pottery; finer varieties used for glazed pottery, which in places has obtained a reputation for artistic merit; fire-clays raised in considerable quantities on some of the Gondwana coal-fields; and fuller's earth, which is mined in the Central Provinces and in Rajputana.

The imports of materials coming under this head show that there is room for the development of the raw materials which are suitable for the manufacture of articles required in a modern civilized community. In 1903 the value of earthenware and porcelain imported amounted to £187,390; of earthenware piping, £6,659; of clay, £6,186; and of bricks and tiles, £38,618.

Copper-ores.

Copper was formerly smelted in considerable quantities in South India, in Rajputana and at various parts of the outer Himalayas where a killas-like rock persists along the whole range, and is known to be copper-bearing in Kulu, Garhwal, Nepal, Sikkim, and Bhutan. Native-made copper has, however, completely given way to the imported material, and all attempts by European companies to open up the

deposits have proved to be unsuccessful so far. Mining leases are still held, and prospecting licenses frequently granted for copper-ores. The Indian purchases of copper and brass form a sensible item in the imports of metals. During the six years under review the average annual value of copper imported was £813,701, whilst during the last three years the copper imported was valued at over a million sterling per annum.

Corundum.

The use of abrasives in manufacturing communities seems to be on the increase, and new forms are being put on the market yearly. Emery formerly served most requirements, until purer forms of corundum were discovered in quantity. The cheaper forms of garnet have long been used to adulterate emery, and members of the spinel family, like hercynite, have been used inadvertently as such. During the last ten years carborundum, manufactured by the cheap electrical power developed in America, has come into use, the production of the United States having now reached about 1,700 tons a year. Artificial corundum is also being manufactured from bauxite at Niagara, and crushed steel is being used to an increasing extent.

Natural corundum has thus many competitors in the market of abrasive materials, and as a large portion of the alumina in igneous magmas is necessarily used up during the processes of consolidation by the silica and bases present, it is theoretically unlikely that the free oxide can exist anywhere in an abundance comparable to the vast quantities of combined alumina in the earth's crust. In most cases the corundum is scattered as isolated crystals through the rock, and only the most economical devices for its separation can make mining remunerative.

In India, where the use of corundum by the old *saikalgar* (armourer, sword-grinder) and lapidary has been known for many generations, the requirements of the country have been met by a few comparatively rich deposits, but it is doubtful if these are worth working for export in the face of the competition referred to above in Europe and America, or will even stand against the importation of cheap abrasives.

There is still, and for many generations has been, a certain trade in Indian corundum, but the returns for production are manifestly incomplete. No workings exist of the kind that could be ordinarily described as mining, but attempts have been made to increase the scale of operations at Palakod and Paparapatti in the Salem district,

near Hunsur in Mysore, and in South Rewa. In 1898, the figures returned showed a production of 7,603 cwt., but the output never approached this figure in any subsequent year.

Corundum is very widely distributed throughout the Mysore State, and is said to occur in every district except Shimoga. The annual production in Mysore has been estimated as follows:—

			£
1898	2,937 cwts., valued at		698
1899	879 "	" "	171
1900	1,386 "	" "	225
1901	1,634 "	" "	357
1902	574 "	" "	108

Much of the corundum, which is a regular item of trade in the bazars of cities like Delhi, Agra and Jaipur, where the Indian lapidary still flourishes, is collected in a casual way by agriculturists and cow-herds, who dispose of it through the village *bania* to the larger dealers of the great cities. Our information as to the mode of occurrence and distribution of the mineral was summarized in a special memoir published by the Geological Survey in 1898.

Since that year interesting developments have occurred in working the corundum in Ontario, Canada, where the mineral occurs in association with nepheline-syenite like that near Kangayam in the Coimbatore district.[1] By the adoption of mechanical means for concentration it has become possible to separate corundum from the felspar rock in which it is embedded, and to put a product on the market, not only for local use, but for export to the United States and Europe. The output of Canadian corundum in 1902 reached 805 tons, which was about double the production of 1901.

Gem-stones.

The most valuable of the precious stones raised in India is undoubtedly the ruby, but this and the other stones obtained in the country do not approach in value the unset stones and pearls imported, which, during the period under review, had an average annual value of £511,206.

Of the precious and semi-precious stones in India, the most important, Amber, Jadeite and Ruby, have been already referred to. Of

[1] T. H. Holland: The Sivamalai series of Elæolite and Corundum-Syenites, *Mem. Geol. Surv., Ind.*, XXX, pt. 3, 1901.

the others, the only ones which are of immediate concern are Beryl, Diamond, Garnet, Sapphire, Spinel, Tourmaline, and Turquois. All of these except the last have been, or are still being, worked to some extent in India, and the Turquois may be dismissed with the mere mention of the fact that India, besides being a large importer for local use, is one of the channels by which the material raised in Persia and adjoining areas reaches the European and Eastern market. The other minerals deserve more particular mention.

Agate.

There is still a considerable trade in agate and the related forms of silica, known under the general name of *hakik*, and obtained from the amygdaloidal flows of the Deccan Trap. The best known and perhaps still the most important of the places at which agate and carnelians are cut and prepared for the market is Cambay, the chief city of the state of that name under the Kaira Political Agency, Bombay Presidency. The agates come from various states and districts on or near the edge of the trap, but mostly from the State of Rajpipla, where the chief source is a conglomerate near the village of Ratanpur. The right to collect *hakik* at Ratanpur is leased for a period of five years at a fixed annual rental, but precise data as to the value of the stones sent to Cambay are not obtainable. A certain amount of agate-cutting is also carried on at Jabalpur, and at a few other places within range of the Deccan Trap.

Much of the agate retailed in Europe is sent from Cambay, and large quantities are also exported to China.

Rock-crystal.

In the Tanjore district, Madras Presidency, fragments of rock-crystal are collected and cut for cheap jewellery, being known as "Vallum diamonds," whilst the bi-pyramidal quartz-crystals found in the gypsum of the salt marl near Kalabagh, on the Indus, are to a certain extent used for making necklaces, and rock-crystal is similarly used for cheap jewellery in Kashmir.

Beryl.

Beryl in its pale-coloured varieties is of common occurrence in the granite-pegmatites of India, but the crystals are generally too much fissured for use as gem-stones. Occasionally in the pegmatite veins which are worked for mica in Behar and in Nellore, large crystals of beryl, many inches across, are found to include clear fragments which might be cut as aqua-marines; but the only places in India where attempts have been made to excavate pegmatite solely for its aqua marines are at Padiyur (Pattalai) near Kangayam, Coimbatore district, and at different places in the Toda

hills in Rajputana. Stones of considerable value were obtained from the mine which was worked at Padyur in the early part of the nineteenth century: a pit some 30—40 feet in depth is still in existence, but no one seems to have taken an interest in the place since J. M. Heath held a lease in 1818. The whole area is impregnated with igneous intrusions, and deserves more attention than it has so far received.

Diamonds: Distribution of, in India.

Notwithstanding the reputation (stretching back even as far as Ptolemy in the European, and further in the Hindu, classics) which India has had as a diamond-producing country, the output of to-day is very small and comparatively unimportant. The places which, according to accounts, have been most productive in the past form three great groups, each in association with the old unfossiliferous rocks of probably pre-Cambrian age now known as the Purána group, and distinguished locally as the Cuddapah and Kurnool systems in South India, and as the Vindhyan system in the northern part of the Peninsula.

Southern group of occurrences.

The southern of the three groups of diamond-occurrences includes localities, with apparently authentic records, in the districts of Cuddapah, Bellary, Kurnool, Kistna, and Godavari. Loose stones have been picked up on the surface of the ground, found in deposits of alluvium and in workings which have been undertaken in the so-called Banaganpilly stage of the Kurnool series of strata.

Eastern group of occurrences.

In the second group of occurrences in the Mahanadi valley, the stones have been found in the alluvium of the Sambalpur and Chanda districts, and though strata similar to those of the Vindhyans and Kurnools are known in this area, no diamonds have been found in these older rocks.

Central Indian occurrences.

The third group of occurrences occupies a tract some sixty miles long by ten miles wide, with the Vindhyan conglomerates near Panna as the centre. The diamond-mining industry still persists in this area, both in the old conglomerate of Vindhyan age, and in deposits which, though described as alluvium, are possibly relics of Lameta (Upper Cretaceous) deposits.

Garnet.

The only garnets worked to any considerable extent in India occur in the mica schists of Rajmahal in Jaipur, and near Sarwar in the adjoining State of Kishengarh.

Returns are not available to show the condition of the industry in Jaipur, but there is still a considerable industry in the Kishengarh State, though the yearly estimates are altogether too variable to permit of a fair average being drawn, varying from about £10,000 to £2,000.

Sapphire.

Sapphires of considerable value were formerly obtained in Zanskar, Kashmir State, but the mines are said to be exhausted, and returns for recent work are not available. Occasionally the normal blue sapphire, and the rarer green, yellow and white varieties are found in the ruby-bearing gravels in Burma.

Spinel.

Spinel is a constant associate of the ruby, both in the gravels and in the limestone, and the crystals, on account of their perfect ruby colour and their octahedral habit, are often mistaken for the true ruby with its eight-faced combination of the basal plane and rhombohedron.

Tourmaline.

Several attempts have been made to work the beautiful red variety of tourmaline (rubellite) which occurs in the Ruby Mines district of Upper Burma. In 1898 an outturn worth £359 was reported for this area, in 1900 the value was estimated at £1,240, and in 1903 at £196, but returns are not available for 1899 and 1902.

Gypsum.

Gypsum occurs in considerable abundance in various parts of India, occurring both in the fibrous form and as clear selenite crystals. In Sind it occurs in beds sometimes 3 to 4 feet thick near the top of the Gáj beds of the Kirthar range; in Cutch it occurs in abundance in the rocks below the Nummulitic limestones; in the Salt Range it occurs in large masses with the salt-marl, lying below Cambrian beds. A very interesting, and, judging by the returns, important occurrence is N.-N.-W. of Nagore in Jodhpur, Rajputana, where a bed, 5 feet thick or more, occurs in silt probably formed in an old salt-lake. From this area an annual average output of 5,394 tons is reported for the years 1898 to 1903. Selenite crystals of similar origin have been recently found in the kankar near the base of the silt in the Sambhar lake.

Glass-making Materials.

The common, impure sands of the rivers and the efflorescent alkali salts, so common in many parts of India, are used in various places for

the manufacture of the inferior varieties of glass used for bangles; but attempts to make the better kinds of glass on a large scale have hitherto failed in India.

The chief difficulty in the way of manufacturing the better grades of glass in India is the absence of known deposits of quartz-sand of the requisite purity and of suitable texture. For the finer qualities of glass, the sand which is, of course, the chief natural substance used, should be rather fine and uniform in grain, angular rather than rounded, and perfectly white. For the commoner kinds of glass, in which colour is of no importance, a considerable quantity of impurity can be tolerated and allowed for in making up the melting charge. The well-known Fontainebleau sand of France, used largely for glass-making, will yield as much as 99 per cent. of silica, with 0·50 per cent. of alumina and a trace of iron oxide; but good window glass can be made from sand containing iron oxide up to ·02 per cent. without the use of the corrective manganese oxide.

To what extent a glass-making industry would find a market in India may be judged by the fact that during the past six years the annual imports of glass and glassware have gradually risen in value from £441,529 in 1898-99 to £661,377 in 1903-04.

Lead, Silver, and Zinc.

Galena alone, or with blende and other sulphide ores, is known in various parts of India and Burma, and has been worked in various places for lead, or lead and silver, under past Native rulers; but the mining of lead-ores has long been extinct, and the only recent attempt calling for special mention is that now being made to develope the deposits near Pang Yung in the Northern Shan States formerly worked by the Chinese, who left behind large heaps of slag reported to be amenable to profitable treatment by modern metallurgical processes for the extraction of silver.

Millstones.

The manufacture of millstones is almost universal in India, any local hard stone being turned to account. On the plains small millstones of about 15 inches in diameter are worked by hand, but in the Himalayas, where a fall of water can be easily arranged, a rude form

of turbine is made to work a heavier stone by a direct-acting vertical shaft, and the ordinary meal of the hill-man is manufactured in these primitive mills. These small mills are familiar objects in a Himalayan valley, but no returns are available to gauge the industry of stone-cutting.

Mineral Paints.

Up to the present the manufacture of mineral paints appears to be very small compared to the demand and the natural resources in minerals apparently suitable. In the Jabalpur district mineral paint-works are utilizing the soft hematites of Jauli and are drawing supplies of yellow ochre from the Panna State, whilst similar works near Calcutta are dependent largely on imported material.

Ochres, red, yellow and of other colours, are commonly used by natives in many parts of the country, in a crude or simply levigated form and are known under the generic name *geru*. A common source of supply is the laterite in the Peninsula and Burma, but well-defined ochres occur in deposits of various geological ages down to the Archæan hematites. In Trichinopoly district yellow ochre is obtained from the Cretaceous rocks, and in Burma large deposits are known amongst the Tertiary beds of the Myingyan district. A black slate near Kishengarh has been successfully tried on the Rajputana-Malwa Railway. Barytes, used as a substitute or adulterant for "white lead," is obtainable in quantity near Alangayam in the Salem district and in the Jabalpur district, but no attempts have been made to turn the deposits to account for paint-making.

Orpiment, the yellow sulphide of arsenic, has been already referred to under "Arsenic" (*supra*, p. 97.)

Mineral Waters.

One curious feature in connection with Indian minerals is the neglect of our numerous hot and mineral springs. To what extent the value of these is purely fanciful is a matter of small concern for the time being; for whether they have the medicinal properties claimed for them or not, there is no doubt that well-advertised mineral waters have an economic value, and numerous varieties from Europe and Japan are scattered over India, and brought to the continual notice of

the travelling public in all railway refreshment rooms. Natives of India have for many ages recognised a value in mineral waters and in the hot springs which are often charged with more than usual quantities of mineral matter. In many cases these, like most unusual natural phenomena, have become sacred to the Hindus, and have consequently become places of resort for pilgrims from great distances. Of instances of this sort may be mentioned the hot springs at Manikarn in Kulu, where the pilgrims cook their rice in the hot springs emerging in the shingle beds close to the ice-cold stream of the Parbatti river. The water is led into the neighbouring temple and rest-house for baths, being supposed to be of value for rheumatism. At Lasundra in the Kaira district, and at Vajrabai in the Thana district, Bombay Presidency, springs of sulphurous water, having a temperature of 115°F., are also resorted to by Hindu pilgrims. Generally it may be said that hot springs, often sulphurous, are common throughout the Tertiary areas of Sind and Baluchistan on one side, and of Assam and Burma on the other side, of India, the distribution being similar (and perhaps dependent on similar causes) to the distribution of petroleum, with its constant associates of salt and gypsum. Other springs occur along the foothills of the Himalayas, in the Kharakhpur hills, etc., sufficiently well distributed to permit of easy transport. The provincial gazetteers contain sufficient references to these springs to guide private enterprise, but more might be done in the way of analysis of the waters, which would be as interesting from a scientific as possibly from an economic point of view. The mineral water of Sitakhund in the Kharakhpur hills is the only one which has been turned to account.

Phosphates.

One regretful feature in connection with the Indian mineral resources is the absence, in a country where agriculture is such a predominant industry, of any phosphatic deposits of value, and a further circumstance to be regretted is the continued export of phosphates in the form of bones, due primarily to the fact that, being without means for the manufacture of cheap sulphuric acid, superphosphates are not made in the country, and the little that is used is imported from Europe. During the past six years the materials imported under the head of manures have varied in value from £6,367 in 1898-99 to £2,144 in

1902-03, whilst the exports of manures, amongst which bones make up 99 per cent. of the total, have been as follows:—

TABLE 60.—*Exports of Manures from India during the years 1897-98 to 1902-03.*

YEAR.	Quantity.	Value.
	Tons.	£
1897-98	72,664	263,500
1898-99	74,971	272,268
1899-00	110,927	408,581
1900-01	113,465	394,228
1901-02	94,243	344,128
1902-03	105,634	381,784
Average	*95,317*	*344,081*

Amongst the phosphatic deposits of India, the principal and perhaps the only one worth considering is the deposit of phosphatic nodules of the septarian kind, occurring in the Cretaceous beds of the Perambalur taluk, Trichinopoly district, Madras Presidency. Dr. H. Warth in 1893 estimated that to a depth of 200 feet the beds contained phosphates to the amount of about 8 million tons, but the nodules are distributed irregularly through clay, varying, in the different deep excavations made, between 27 and 47 lbs. per 100 cubic feet, and in some shallow diggings 70 lbs. per 100 cubic feet. Analyses of these nodules show them to contain from 56 to 59 per cent. of phosphate, and about 16 per cent. of carbonate of lime, with considerable variations in different nodules. The alumina and oxide of iron vary between 4 and 8 per cent.

Two attempts made to dispose of these phosphates in a finely powdered condition for use as a fertilizer on coffee plantations in South India were reported to be unprofitable, and mining leases have consequently not been applied for. No attempts have been made to export the material. Its value would possibly be about the same as a

third-grade Algerian phosphate, which brings about £1 a ton delivered at European ports, and as the sea freight from Madras would be added to the cost of a railway journey of 248 miles and cartage of 20 miles, there is no present prospect of profitable mining for export.

Small quantities of apatite are turned out and thrown away with the waste in the Hazaribagh and Nellore mica-mining areas, and a few other occurrences of unknown, and presumably smaller, value have been reported at different places—near Mussoorie, in East Berar, and in the eocene shales above the coal near Dandot colliery in the Punjab Salt Range.

Rare Minerals.

Minerals of the so-called rare metals have received hitherto practically no attention in India, although some are known to exist in the country, and others, judging by the geological conditions, might be hopefully searched for. Molybdenite has been found as isolated crystals in pegmatite and quartz-veins in parts of Chota Nagpur; tungsten occurs in the mineral wolfram as a common associate of tin-ores in South Burma and in the Southern Shan States; platinum and iridium have been found in the auriferous gravels of the rivers draining the slopes of the Patkoi ranges, both on the Assam and the Burma sides; uranium-ores have been detected in the mica-bearing pegmatites of the Singar mica mine in the Gaya district, occurring as pitchblende, torbernite and uranium-ochre; titanium is widely distributed in the form of ilmenite and sphene; and zircon occurs associated with the elæolite-syenites in the Coimbatore district. Of these minerals possibly the wolfram (tungstic ore) of Burma offers the best prospects of immediate development.

No undoubted occurrence has been recorded of the minerals which are valuable, like monazite and the new Ceylon mineral thorianite, on account of the incandescent rare earths they contain, although some of these minerals are very widely distributed amongst crystalline rocks resembling those of Peninsular India. Columbite, tscheffkinite, gadolinite, and allanite containing helium have, however, been definitely determined in India.

Slate.

Slate-quarrying gives a means of livelihood to numbers of workers along the outer Himalayas, where the foliated rocks, though often not

true clay slates, possess an even and perfect fissility which enables them to be split for slabs and even fine roofing slates. In the Kangra district a joint-stock company has organized the work in a systematic manner, and for the past six years has declared dividends of 12 per cent. with the addition of considerable sums to the reserve funds. The same company works quarries in clay-slate amongst the Aravalli series near Rewari, south of Delhi.

In the Kharakpur hills, a private company is working a slightly metamorphosed phyllite, which, though not giving the thinnest varieties of roofing slate, produces fine slabs, for which a more extended use is continually being found. Slate is also being worked in various parts of the so-called transition series of rocks on the Peninsula; but no figures are available to show the extent of the trade.

Sodium Compounds.

Besides sodium chloride other salts of soda, notably the sulphate (*khari*) and carbonate (*sajji*), accumulate in the soil of areas where the climate is dry, and both the sulphate and carbonate are prominent amongst the sodic compounds in the brine of the Rajputana salt lakes. A conspicuous instance of a salt lake in which the carbonate is most prominent is the crater-like Lonar lake occurring as a roughly circular depression in the Deccan trap-flows of Berar.

Besides the impure *sajji-matti*, of which considerable quantities are still in use, the trade statistics show that imports are distinctly increasing, and that common country *sajji* is becoming displaced. For information concerning the alkali compounds used and manufactured in India, see *Agricultural Ledger*, No. 5 of 1902, published by the Reporter on Economic Products, Calcutta.

Steatite.

One of the most widely distributed minerals in India is steatite, either in the form of a coarse potstone—so-called on account of its general use in making pots, dishes, etc.,—or in the more compact form suitable for carvings, and in its best form, suitable for the manufacture of gas-burners. There is a trade of undetermined value in nearly every province, but it is impossible to form even a rough estimate of its value. An exhaustive account of the Indian occurrences of steatite was published by Mr. F. R. Mallet in the *Records*,

Geological Survey of India, vol. XXII, part 2 (1889), and a note by Mr. H. H. Hayden in vol. XXIX (p. 71) of the same publication adds further details with regard to the deposits in Minbu district, Burma, where the annual outturn is estimated to be worth from £300 to £500. The returns, which are confessedly incomplete, give an average annual production in India of about 35,000 tons, valued at £1,900.

Sulphur, Sulphuric Acid, and Soluble Sulphates.

Sulphur.

Small quantities of sulphur are obtainable on the dying volcano of Barren Island, and on some of the volcanoes in Western Baluchistan, whilst it has been reported in connection with the petroliferous Tertiary rocks in the Baluchistan-Persian belt, as well as in the Arakan system on the east. There are, however, no deposits of free sulphur known to be worth working.

Pyrite is known in various parts of India, and in one place, near Kalabagh on the Indus, it is sufficiently abundant in the shales which have been worked for alum to give rise to frequent cases of spontaneous combustion. An occurrence of this sort is one that, suitably placed, might be of value as a source of sulphur. Otherwise, the only chance of sulphur to compete with the imported article is bound up in the problem of developing the metalliferous sulphides for both metal and sulphur.

Sulphuric acid.

In view of the value of the imports of sulphur and sulphuric acid, and in consideration of the fact that a cheap supply of the acid would be the key to many industries now either non-existent or in a feeble condition, the manufacture of sulphuric acid on a large scale and cheaply would be the starting point of an economic revival. During the six years under review the imports of sulphur averaged 34,136 cwts. a year, valued at £12,612, whilst the annual average for sulphuric acid was 45,374 cwts., valued at £32,273. A small quantity of the acid, on an average 250 cwts. a year, was re-exported, chiefly to British East Africa. In addition to sulphuric acid, there are several chemicals imported which could be produced in India more cheaply if the acid were made in the country in large quantities at a sufficiently low price. The average annual value of imported "chemicals for paper-making" alone has been £54,810 during the past six years, and if, as seems likely, an attempt is made to turn the bye-products in coke-making

to account, the demand for sulphuric acid will increase, whilst the only chance of these industries springing up will depend on the possibility of obtaining a cheap supply of sulphuric acid.

Sulphates of iron and copper.

For many years pyritous deposits in India have been turned to account for the manufacture of soluble sulphates of iron and copper. The case of alum has been referred to already (*supra*, p. 94), and with the alum, which was formerly obtained in quantity from the decomposed pyritous shales at Khetri and Singhana in Rajputana, copperas and blue vitriol were also obtained. No statistics are, however, available with regard to the history of these industries, which have had to give way to the importation of cheap chemicals from Europe.

Through the accident of an alphabetical arrangement, the last subject to be considered enables us to point the lesson taught by a general survey of progress (*cf.* page 7). Sulphuric acid is the key to most chemical and to many metallurgical industries; it is essential for the manufacture of superphosphates, the purification of mineral oils and the production of ammonium sulphate, various acids, and a host of minor products; it is a necessary link in the chain of operations involved in the manufacture of the alkalies, with which are bound up the industries of making soap, glass, paper, oils, dyes and colouring matters; and, as a bye-product, it permits the remunerative smelting of ores which it would be impossible otherwise to develop. During the last hundred years the cost of a ton of sulphuric acid in England has been reduced from over £30 to under £2, and it is in consequence of the attendant revolution in the European chemical industries, aided by increased facilities for transport, that in India the manufacture of alum, copperas, blue vitriol and the alkalies have been all but exterminated; that the export trade in nitre has been reduced instead of developed; that copper and several other metals are no longer smelted; that the country is robbed every year of nearly 100,000 tons of phosphatic fertilizers; and that it is compelled to pay over 10 million sterling for products obtained in Europe from minerals identical with those lying idle in India.

Although sulphuric acid and the alkalies are essential to so many other industries, the conditions for their profitable manufacture will balance the "protective" effect of transport charges only when there is a market in the country for the bye-products which are now essential parts of the cycle of operations in a chemical industry. These

conditions, as shown by the import statistics, are rapidly ripening, but the enterprising capitalist should remember, also, that the present requirements of India represent but a fraction of the consumption which will follow any material reduction in prices by local production.

LIST OF PLATES.

PLATE 1.—Diagram showing the imports of foreign and the exports of Indian coal in statute tons during the decade 1894–1903.

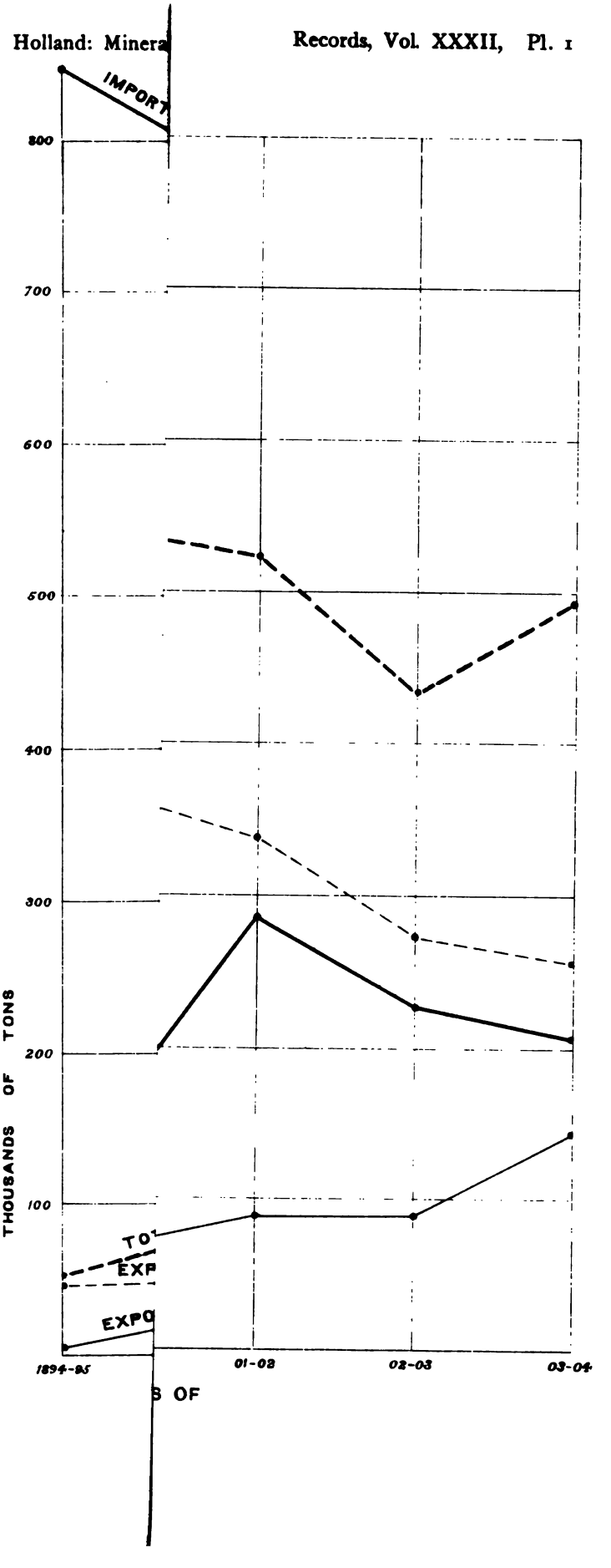
PLATE 2.—Diagram showing the provincial output of coal in statute tons for the years 1884—1903. The output for Bengal is necessarily omitted from a diagram on this scale, but is shown in figure 1, p. 9.

PLATE 3.—Progress of the Warora colliery since the commencement in 1871. For details of the last six years, see p 32.

PLATE 4.—Output of the principal salt-producing countries. The information for Foreign countries has been obtained mainly from *Mineral Industry*.

PLATE 5.—Production of the Upper Burma oil-fields for the decade 1894—1903, stated in Imperial gallons.

PLATE 6.—Map showing the occurrences of petroleum in Assam and Burma, prepared by Mr. T. D. LaTouche, B.A., F.G.S., Superintendent, Geological Survey of India.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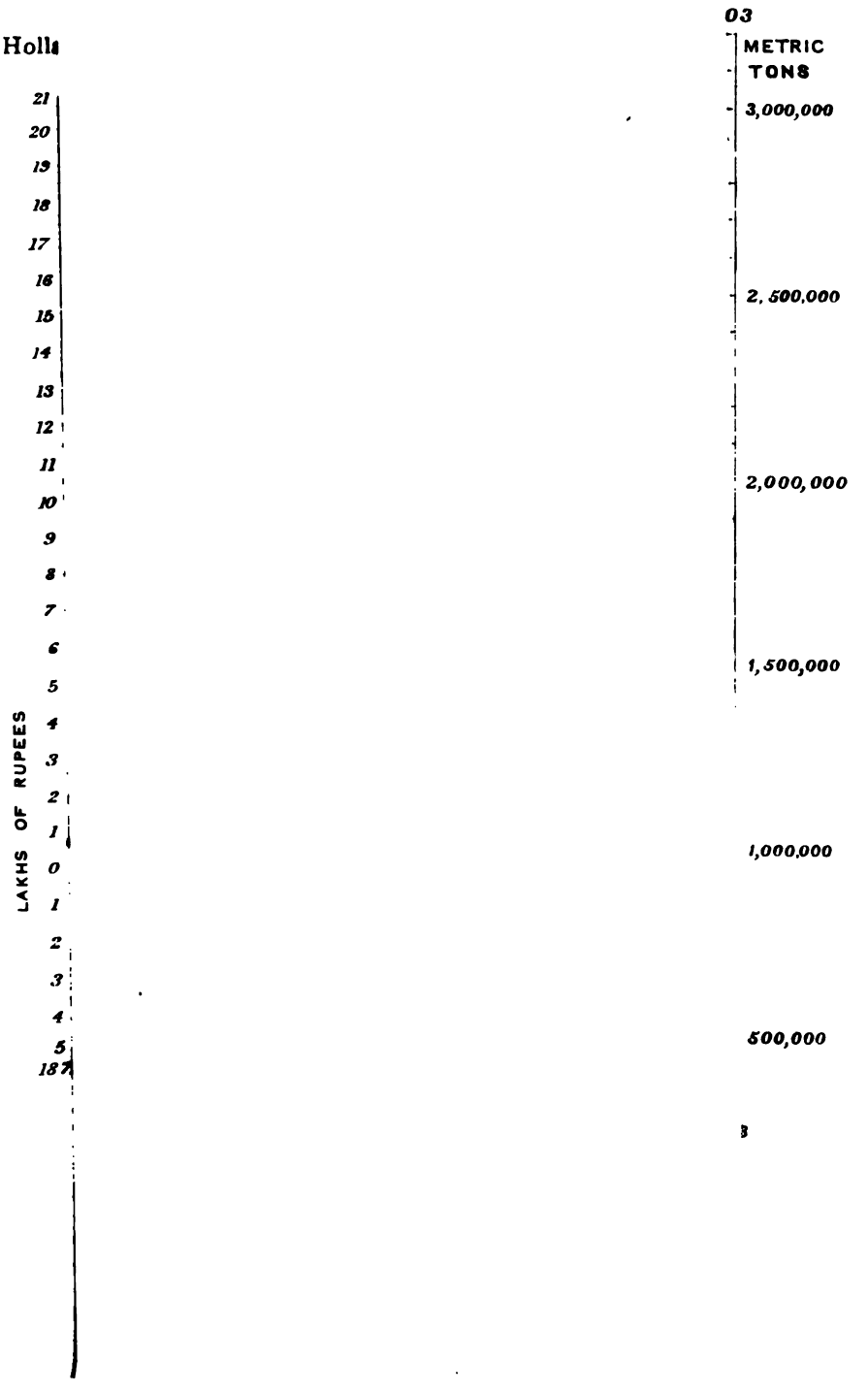
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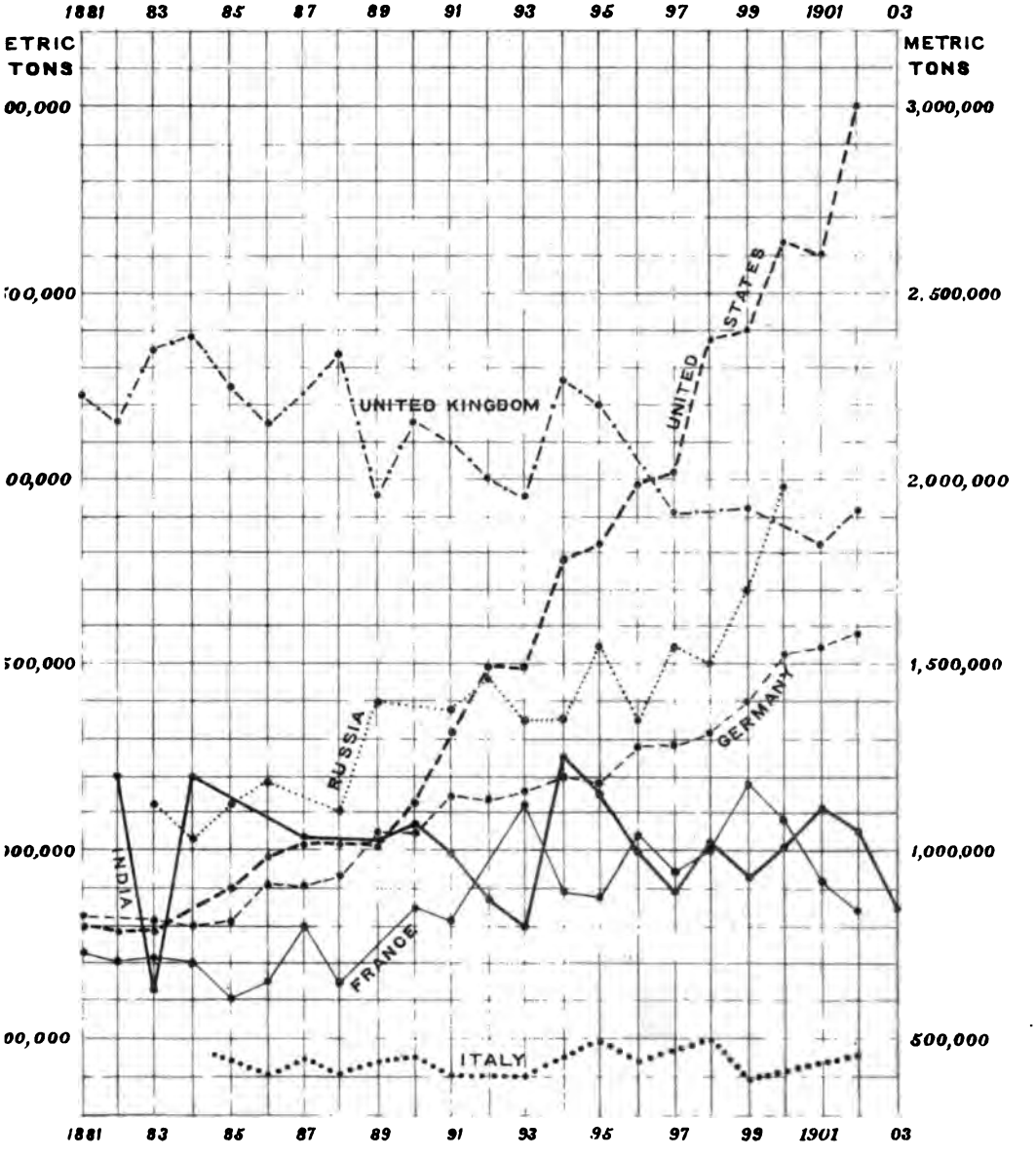
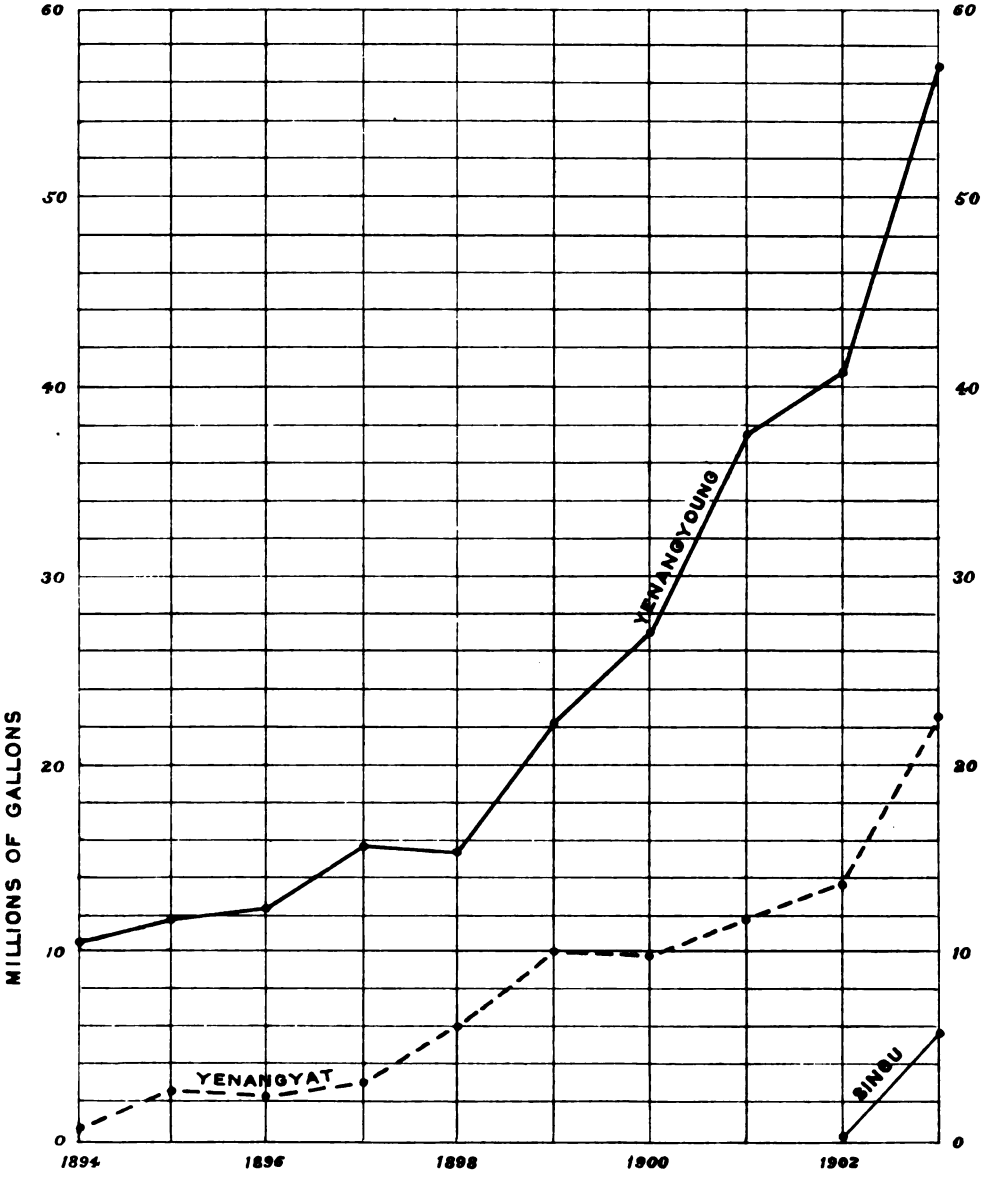
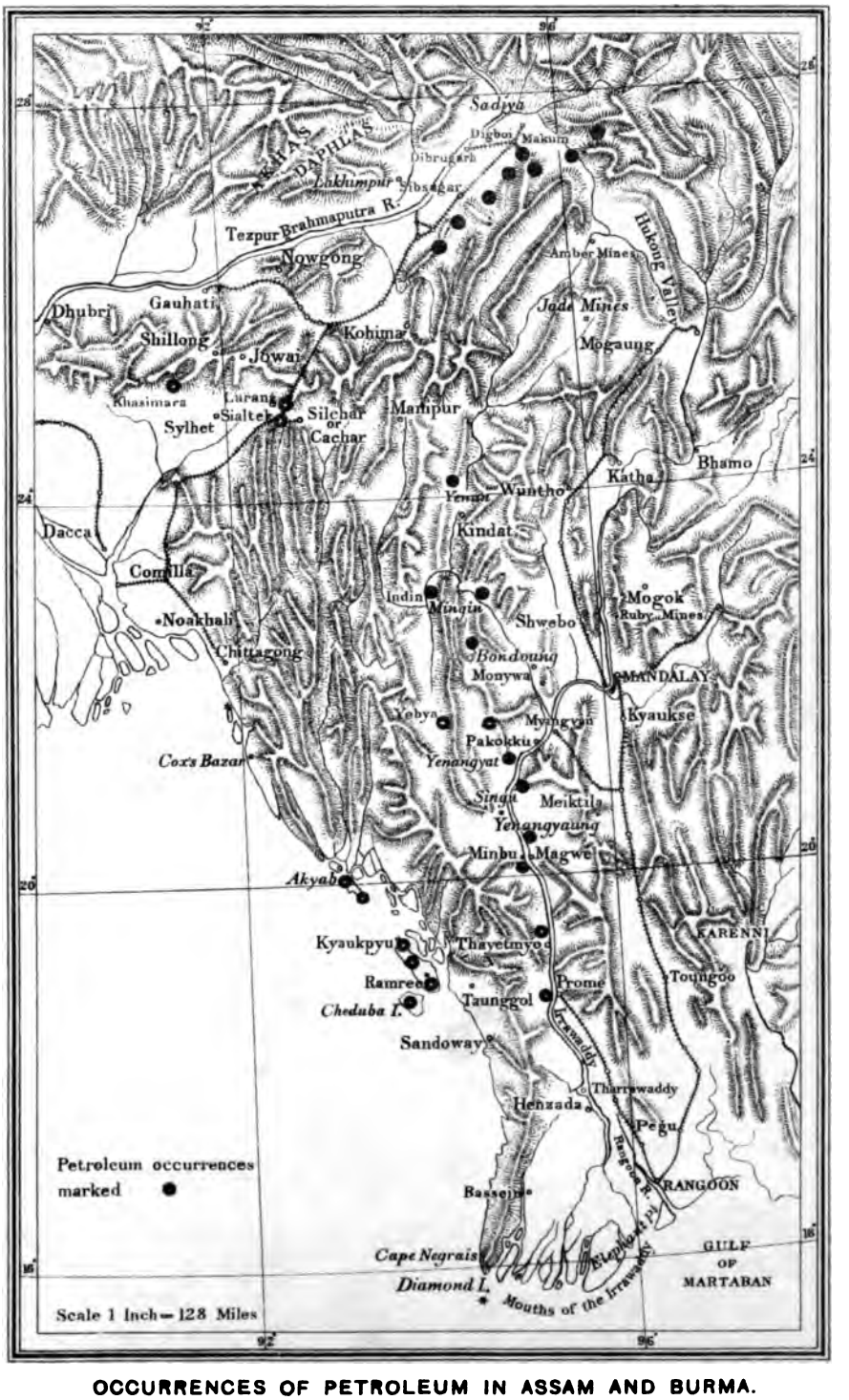


OUTPUT OF PRINCIPAL SALT-PRODUCING COUNTRIES.



PRODUCTION OF UPPER BURMAH OILFIELDS.



OCCURRENCES OF PETROLEUM IN ASSAM AND BURMA.

Part 4.—Note on the progress of the gold industry in Wynaad, Nilgiri district. Notes on the correspondence of the Upper Gondwana series in Trichinopoly and Nellore-Kistna districts. Senarmontite from Narsapur.

Part 5.—On the geographical distribution of fossil organisms in India. Submerged forest on Bombay Island.

Vol. XII. 1870.

Part 1.—Annual report for 1869. Geology of Kashmir (third notice). Further notices of Siwalik mammalia. Notes on some Siwalik birds. Notes of a tour through Hangrang and Spiti. On a recent mud eruption in Basrit Island (Arakan). On Brucite, with Rhodonite, from near Nagpur, Central Provinces. Palæontological notes from the Satpura sandstone. Statistics of coal importations into India.

Part 2.—On the Mokponi coal-field. On Eozoonite with Pentremites occurring at Gwalior, Jubulpur district. A geological reconnaissance from the Indus at Kushalgarh to the Kurram at Thal on the Afghan frontier. Further notes on the geology of the Upper Punjab.

Part 3.—On the geological features of the southern part of Madura district, the Pudukota State, and the southern part of the Tanjore and Trichinopoly districts included within the limits of Sheet No. of the Indian Atlas. Rough notes on the cretaceous fossils from Trichinopoly district, collected in 1869-70. Notes on the genus Sphenopteris and other Equisetaceæ, with reference to the Indian forms Trizygia Speciosa, Royle (Sphenophyllum Trizygia Koyle). On Mysorite and Amesmite from the Shimoga district. On corundum from the Jehool Hills. On the Jogs neighbourhood and old mines on the Nerbudda.

Part 4.—On the 'Attock Slates' and their probable geological position. On a complete knee of an undescribed tortoise, from the Upper Siwaliks, near Nila in the Pathwar, Punjab. Sketch of the geology of North Arcot district. On the continuation of the road section from Murree to Abbottabad.

Vol. XIII. 1880.

Part 1.—Annual report for 1879. Additional notes on the geology of the Upper Godavari basin in the neighbourhood of Sironcha. Geology of Ladak and neighbouring districts, being fourth notice of geology of Kashmir and neighbouring territories. Traps of Coast Sales from Bacul Island and the Panjim. Note on the fossil genera Nöggerathia, Stur., Noggerathiopsis Feist., and Rhiptozamites Schmalh., in palæozoic and secondary rocks of Europe, Asia, and Australia. Notes on fossil plants from Kattywar, Khasia Hills and Jhingpur. On volcanic dust of eruptive in the Kankar.

Part 2.—Geological notes. Palæontological notes on the lower trias of the Himalayas. On the artesian wells at Pondicherry, and the possibility of finding such sources of water-supply at Madras.

Part 3.—The Kamptee trap. On the discovery of a unit of palæolithic type in the Punjab. Palæontological notes from the Karharbari and Raniganj coal fields. Further notes on the correlation of the Gondwana flora with that of the Australian coal-bearing system. Note on reh or alkali soils and saline well waters. The fossils of Upper India. Note on the Nizam Tal landslip, 28th September 1880.

Vol. XIV. 1881.

Part 1.—Annual report for 1880. Geology of part of Darjiling, Bhutan, and neighbouring districts, being fifth notice of the geology of Kashmir and neighbouring territories. Note on some Siwalik carnivora. The Siwalik group of the Sub-Himalayan region. On the South Rewah Gondwana basin. On the boulder-beds associated with the basaltic rocks of north-western Deccan, in relation to Indian glaciation. On some Rajmahal plants. Tree-clad ridges of the Punjab. Appendix to 'Palæontological notes on the lower trias of the Himalayas.' On a new cretaceous Lamellibranch from Perim Island in the collection of the Bombay Branch of the Royal Asiatic Society.

Part 1.—The Nahan-Siwalik unconformity in the Northwestern Himalaya. On some Cretaceous vertebrates. On the cretaceous beds of Hundes in Tibet. Notes on mining records, and the mining record office of Great Britain; and the Coal and Metalliferous Mines Acts of 1872 (England). On yuksilite and damalite from the Khetri mines, Rajputana, with some remarks on jaspilite (hypersthene). On the occurrence of zinc ore (Calamine and Blende) with baryies, in the Karnul district, Madras. Notice of a mud eruption in the island of Cheduba.

Part 2.—Arrasan borings in India. On oligoclase granite at Wangtu on the Sutlej, North-west Himalayas. On a fish-palate from the Siwaliks. Palæontological notes from the Hazaribagh and Lohardagga districts. Undescribed fossil carnivora from the Siwalik hills in the collections of the British Museum.

Part 3.—Remarks on the nomination of geological nomenclature and cartography. On the geology of the Arvali region, central and eastern. On a specimen of native sesquioxide of tin from Pulo Ubin, near Singapore. On Turgite from the neighbourhood of Juggerpett, Nimnah district, and on zinc carbonate from Karnul, Madras. Note on the section from Dalhousie to Pangi, viâ the Sach Pass. On the South Revah Goudwana Lower Submerged forest on Bombay Island.

Vol. XV, 1878.

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Part 2.—The refinement of Dr. Oldham. On the age of some fossil floras in India. Diagnosis of a remnant of Zingiber Ganesa, with notes on the sub-genus and allied forms. Note upon the Sub-Himalayan strata in the Jaeni (Jumnoo) Hills.

Part 3.—On the age of some fossil floras in India. On the geological age of certain groups comprised in the Gondwana series of India, and on the evidence they afford of distinct zoological and botanical terrestrial regions in ancient epochs. On the relations of the fossiliferous strata at Maleri and Kota, near Sironcha, C. P. On the fossil mammalian fauna of India and Burma.

Part 4.—On the age of some fossil floras in India. On the osteology of Merycopotamus dissimilis. Addenda and Corrigenda to paper on tertiary mammalia. Occurrence of Pteropodous in India. On the geology of the Ft Punjal and neighbouring districts.

Vol. X, 1877.

Part 1.—Annual report for 1876. Geological notes on the Great Indian Desert between Sind and Rajpootana. On the occurrence of the cretaceous genus Omphalia near Namebo lake, Tibet, about 78 miles north of Lhassa. On Rathoon in the Goodwana formation. Notices of new and other vertebrata from Indian tertiary and secondary rocks. Description of a new Emydine from the upper tertiaries of the Northern Punjab. Observations on under-ground temperature.

Part 2.—On the rocks of the Lower Godavari. On the 'Algah Sandstones' near Cuttack. On fossil floras in India. Notices of new or rare mammals from the Siwaliks. On the Aravali series in North-eastern Rajpootana. Borings for coal in India. On the geology of India.

Part 3.—On the tertiary and underlying rocks in the North-west Punjab. On fossil floras in India. On the occurrence of erratics in the Panjal. On recent coal explorations in the Darjiling district. Limestones in the neighbourhood of Darjiling. On some forms of blowing-machine used by the smiths of Upper Assam. Analyses of Raniganj coals.

Part 4.—On the Geology of the Mahanadi basin and its vicinity. On the diamonds, gold, and lead ores of the Sambalpur district. Note on 'Leyon Comp. Barrovensis' McCoy, from the Silurian group near Madras. On fossil floras in India. The Blaini group and the 'Central Gneiss' in the Simla Himalayas. Remarks on some statements in Mr. Wynne's paper on the tertiaries of the Northwest Punjab. Note on the genera Choeromorya and Hhagetherium.

Vol. XI, 1878.

Part 1.—Annual report for 1877. On the geology of the Upper Godavari basin, between the river Wardha and the Godavari, near the civil station of Sironcha. On the geology of Kashmir, Kishtwar, and Pargi. Notices of Siwalik mammals. The palæontological relations of the Gondwana system. On 'Remarks &c., by Mr. Theobald upon erratics in the Punjab.'

Part 2.—On the Geology of Sind (second notice). On the origin of the Kumaun lakes. On a slip over the Milam Pass, Kumaun. The mud volcanoes of Baren and Cheduba. On the mineral resources of Ramri, Cheduba, and the adjacent islands.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1905. [April.

GENERAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA FOR THE PERIOD APRIL 1903 TO DECEMBER 1904. BY T. H. HOLLAND, F.R.S., *Director.*

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INTRODUCTION.

Period of Report.

THIS Report covers the work done by the Department between the beginning of April 1903 and the end of December 1904, the composite period being adopted to permit of a reversion to the system followed, up to the end of 1896, of reporting results in periods of calendar years instead of during financial years. Of the ordinary field season, which lasts in India from early in November to about the end of April, the first two months are necessarily taken up with preliminary traverses in a new area, whilst the latter part, after the beginning of January, is naturally the most fruitful in results. As the work at head-quarters is the natural complement of the field work, and is invariably necessary for its interpretation, the system of reporting at the end of the first quarter, which is found to be convenient for Departments in which financial results are of direct importance, would separate halves of the geological working year which should be naturally joined, and would bring together unrelated parts of two separate years. The system now adopted of reporting by calendar years, however, permits of the field observations being joined to the succeeding recess results, the conclusions of which attain a greater degree of finality through the full discussion of progress reports by the whole body of officers assembled at head-quarters.

2. The distinct revival of interest in Indian minerals, which has occurred during the past year, has been one of the means by which we have had new material of interest brought to our notice, and has been the cause of an increase in the work of the Laboratory altogether beyond the capacity of the Curator and his Assistant; but the extraordinary series of results, of scientific interest as well as of immediate economic value, is due mainly to the enthusiasm and energy displayed by my colleagues, amongst whom I find it impossible to make a selection for special notice.

Officers' Meetings.

3. A more perfect acquaintance with one another's work, a closer approach to uniformity in nomenclature, and, through mutual criticism, a distinct development in quality of finished product, have resulted largely from the newly organized, bi-weekly meetings of the whole Department during the

recess term, when all papers and reports are discussed, and often revised, before submission to Government or issue to the public.

DIRECTOR'S TOURS.

4. Besides the visits to different parts of the country in connection with the engineering enquiries referred to below in paragraphs 37 and 38, the Director's tours have included—(1) visits to Bombay to discuss the proposed boring for artesian water north-east of Wadhwan in Gujarat, and to consult the Bombay Government with reference to reported mineral discoveries in the Panch Mahals; (2) tours in the Central Provinces to examine certain manganese-ore deposits and some new occurrences of bauxite; (3) a tour in Rajputana to superintend the boring work in the Sambhar salt-lake, to examine certain marble quarries, copper deposits and the newly discovered sodalite localities in Kishengarh, and to make a traverse of the Aravalli schists near Ajmer; (4) a visit to the Monghyr district to examine the slate formation of the Kharakhpur hills; (5) to the Raniganj coal-field in connection with boring operations being conducted by the East Indian Railway Company to test the eastward extension of the coal-field under the Damuda alluvium.

DISPOSITION LIST.

5. During the period under report the officers of the Department were employed as follows:—

Superintendents.

Mr. R. D. Oldham . .	At head-quarters till 21st March 1903; posted to Jammu and Kashmir, and returned on the 16th October 1903.
Mr. Tom D. La Touche .	Returned from leave on the 23rd June 1904; posted to Northern Shan States, Burma, and left for the field on the 4th November 1904.
Mr. C. S. Middlemiss .	Deputed to Ceylon on the 22nd April 1903, and returned to head-quarters on the 4th June 1903. Posted to the Vizagapatam hill-tracts and Eastern Godavari district on the 14th November 1903; returned to head-quarters on the 23rd May 1904. Posted to Central India on the 1st November 1904.

Mr. H. H. Hayden . .	Deputed to Madras on the 7th April 1903, and returned to head-quarters on the 16th June 1903. Posted to the Tibetan Frontier Mission on the 6th September 1903, returning to head-quarters on the 24th September 1904.

Deputy Superintendents.

Mr. P. N. Bose . .	Returned from Assam on the 19th May 1903. Posted to Assam on the 16th October 1903, and returned to head-quarters on the 24th November 1903.
Mr. P. N. Datta . .	Returned from the Northern Shan States, Burma, on the 25th May 1903. Deputed to the same area on the 8th November 1903, and returned to head-quarters on the 19th May 1904. Deputed to the Central Provinces, and left for the field on the 20th November 1904.
Mr. F. H. Smith . .	Returned to head-quarters from Chota Nagpur on the 23rd April 1903.
Mr. E. Vredenburg . .	At head-quarters as Curator throughout the period.
Mr. L. L. Fermor . .	Returned to head-quarters on the 18th April 1903. Posted to the Central Provinces for examination of the manganese-ore deposits on the 17th October 1903, returning to head-quarters on the 8th May 1904. Deputed to the Central Provinces, Bombay, and Madras for completion of the examination of the manganese-ore deposits, and left for the field on the 29th October 1904.
Mr. Guy E. Pilgrim . .	Returned from Burma on the 14th May 1903. Deputed to Nasik district, Bombay, on the 21st January 1904, and returned on 22nd February 1904. Posted to the Persian Gulf, and left head-quarters on the 5th November 1904.

Assistant Superintendents.

Mr. G. H. Tipper . .	Joined the Department on the 5th December 1903. Deputed to accompany Mr. La Touche to Burma on the 4th November 1904, subsequently posted to the North Andaman Exploration Party, which he joined on the 18th November 1904.
Mr. H. Walker . .	Joined the Department on the 15th October 1904, and deputed to accompany Mr. Middlemiss on the 1st November 1904.

Palæontologist.

Dr. F. Noetling . .	At head-quarters till the 15th October 1903.

Mining Specialists.

Mr. R. R. Simpson . .	Returned to head-quarters on the 12th May 1903. Posted to the Jammu territory on the 3rd November 1903 for continuation of coal investigation. Returned to Calcutta on the 12th January 1904. Deputed to Madras for examination of site of Somesaram dam on the 8th February 1904, and returned to head-quarters on the 18th idem. Deputed to Mohpani for examination of the coal-field on the 17th March 1904, and returned to Calcutta on the 27th idem. Posted to the Northern Shan States for survey of Lashio and Namma coal-fields, and left on the 1st November 1904.
Mr. J. M. Maclaren . .	Returned to Calcutta on the 16th April 1903. Deputed to the Kolar Gold-field, Madras, on the 1st September 1903, and returned to head-quarters on the 24th idem. Posted to Assam on the 7th November 1903, returned to Calcutta on the 8th May 1904. Posted to the Bellary and Dharwar districts for examination of the auriferous tracts and left for the field on the 29th October 1904.

Sub-Assistants.

Hira Lal . . .	At head-quarters till the 16th May 1904.
S. Sethu Rama Rau .	Joined the Department on the 11th February 1904. Deputed to accompany Mr. Middlemiss on the 1st November 1904.
M. Vinayak Rao . .	Joined the Department on the 26th October 1904. Deputed to accompany Mr. Maclaren on the 29th October 1904.

Assistant Curator.

Mr. T. R. Blyth . .	Was on duty at head-quarters throughout the period.

ADMINISTRATIVE CHANGES.

Retirements.

6. A considerable number of changes have occurred in the staff during the period under report, the balance of result being a deficiency of three graded officers below the sanctioned strength of the Department. The Department has not only been undermanned by retirements, but a number of officers have been on leave, and the effect of a diminished numerical strength has been accentuated by the fact that the newly-appointed officers have necessarily to undergo a period of probation before they are fully efficient.

7. Mr. P. N. Bose retired on the 1st of December 1903, and Mr. R. D. Oldham on the 1st May 1904; and Mr. F. H. Smith resigned through ill-health on the 29th July 1904, whilst Dr. F. Noetling's services were dispensed with by order of the Governor-General in Council from the 15th October 1903. The two Sub-Assistants, Kishen Singh and Hira Lal, having completed their period of service for pension, retired on the 6th June 1903 and the 16th May 1904, respectively.

Retirement of Mr. R. D. Oldham.

8. This review of the changes which have taken place in the staff since the issue of the last report affords the pleasurable opportunity of recalling the extent and value of Mr. R. D. Oldham's services, as a partial compensation for the regret with which his retirement from active work in India has been received by all his colleagues.

Mr. Oldham joined the Department in 1879, with the advantages of an all-round training which has shown itself in the breadth of field covered by his unusually heavy record of literary productions. As the son of the founder of the Department, and the relative of some past members, he brought with him the inspiration of family traditions, which gave rise to a manifest identity of his own interests with those of the work and the service to which he has devoted the most valuable part of his life. During a service of 24 years Mr. Oldham's field-work covered parts of every province in India, and the variety of subjects in which he was interested is shown by his contribution of some 40 papers and memoirs to the Survey publications, besides numerous contributions to extra-departmental journals. His selection by the late Dr. W. King for the work of revising the official Manual correctly expressed the feelings of the other officers with regard to his superiority in knowledge of general Indian geology, whilst his latest large work, on the great earthquake of the 12th June 1897, may be taken as a representative sample of his papers, which invariably passed beyond the purely descriptive stage in applying newly-acquired data to the revision of the current ideas concerning the standard theories which make science of practical value.

New Appointments.

9. So far only two recruits have been appointed to fill the vacancies on the graded list: Mr. G. H. Tipper, B.A., who joined the service on the 5th December 1903, and Mr. H. Walker, A.R.C.S., F.G.S., who joined the service on the 15th October 1904, the first of these two officers being appointed to fill the vacancy caused by Mr. C. L. Griesbach's retirement on the 25th February 1903.

The two vacancies for Sub-Assistants were filled by the appointment of S. Sethu Rama Rau, B.A., on the 11th February 1904, and of M. Vinayak Rau, B.A., on the 26th October 1904.

Promotions.

10. In consequence of the vacancies caused in the higher grades, Mr. H. H. Hayden was promoted to be Superintendent with effect from the 2nd May 1904; Mr. Vredenburg was appointed to be Deputy Superintendent with effect from the 1st December 1903, and Messrs. L. L. Fermor and G. E. Pilgrim, on the completion of their period of probation, were promoted to be Deputy Superintendents with effect from the 29th October 1904. Mr. G. E. Pilgrim has also been appointed to officiate as Palæontologist, with effect from the 15th October 1903.

Leave.

11. Mr. La Touche, Superintendent, returned from furlough and rejoined his appointment on the 23rd June 1904; Mr. R. R. Simpson, Mining Specialist, was granted privilege leave from the 20th July to the 25th October 1904; Mr. P. N. Datta, Deputy Superintendent, was granted privilege leave from the 3rd October to the 4th November 1904; Mr. H. B. W. Garrick, Artist, was granted combined leave for 15 months from the 18th February 1904; Sub-Assistant Hira Lal was granted privilege leave for 28 days from the 31st August 1903. In addition to the above, the officers who retired at the end of their leave were Mr. F. H. Smith, who was granted combined privilege and special leave for six months from the 29th May 1903, afterwards extended on medical certificate to the date of his resignation; Mr. R. D. Oldham, who was granted combined privilege and special leave for six months from the 2nd November 1903; and Sub-Assistant Kishen Singh, who was granted leave on medical certificate for six months from 27th January 1902, extended to the date of his retirement on medical certificate.

INTERNATIONAL GEOLOGICAL CONGRESS.

12. The Department was represented at the International Geological Congress at Vienna in August 1903 by Mr. C. L. Griesbach, C.I.E., late Director, and by Mr. T. D. La Touche, Superintendent. The separate reports of the delegates were forwarded to Government.

ST. LOUIS EXHIBITION.

13. The Department was invited to send a collection to the St. Louis Exhibition, but the pressure of urgent work on a small staff made it impossible to arrange for the preparation of a collection of specimens, and our contribution, consequently, was limited to the exhibition of a set of the Departmental publications, with unfolded duplicates of published maps. For this exhibit the judges awarded two grand prizes, one in the class for maps, and the other in the class for literature relating to mining and geology.

PUBLICATIONS.

Records.

14. During the past year the *Records* of the Department, which were issued as yearly volumes between the years 1868 and 1897, were revived, and the four parts, forming volume XXXI, containing the following papers and notes,

fairly illustrate the range of interests with which the Department has been concerned :—

On a deposit of Copper Ore near Komai, Darjeeling District, by H. H. Hayden, B.A., B.E., F.G.S.

Note on the Zewan Beds in the Vihi District, Kashmir, by R. D. Oldham, A.R.S.M., F.G.S.

Report on the Coal Deposits of Isa Khel, Mianwali, Punjab, by R. R. Simpson, B.Sc.

Report on the Um-Rileng Coal-Beds, Assam, by P. N. Bose, B.Sc., F.G.S.

Note on a Sapphirine-bearing Rock from the Vizagapatam District, by C. S. Middlemiss, B.A., F.G.S.

Lieut.-General C. A. McMahon, F.R.S., by T. H. Holland, F.R.S.

Note on *Cyclolobus Haydeni*, Diener, by Professor C. Diener, Ph.D.

The Auriferous Occurrences of Chota Nagpur, Bengal, by J. Malcolm Maclaren, B.Sc., F.G.S.

On the feasibility of introducing modern methods of Coke-making at the East Indian Railway Collieries, by T. H. Ward, A.M.I.C.E., F.G.S.

The Upper Palæozoic Formations of Eurasia, by Th. Tschernyschew, Director of the Russian Geological Committee, translated by Professor P. Brühl.

Note on the Glaciation and History of the Sind Valley, Kashmir, by R. D. Oldham, A.R.S.M., F.G.S.

On the Occurrence of a Species of *Halorites* in the Trias of Baluchistan, by E. Vredenburg, B.A., B.L., A.R.C.S.

Notes on the Geology and Mineral Resources of Mayurbhanj, by P. N. Bose, B.Sc., F.G.S.

The Geology of Upper Assam, by J. Malcolm Maclaren, B.Sc., F.G.S.

The Auriferous Occurrences of Assam, by J. Malcolm Maclaren, B.Sc , F.G.S.

On a curious occurrence of Scapolite from the Madras Presidency, by E. Vredenburg, B.A., B.L., A.R.C.S.

Miscellaneous Notes on —

Tin-ore and Gadolinite in Palanpur.

Tin-ore in Burma.

Elæolite and Sodalite-Syenites in Kishengarh.
Gem-sands from Ceylon.
Gem-sands from Burma.
Prehnite in Las Bela.
Cretaceous fossils from Persia.
Ancient kitchen-midden in the Andamans.
Selections from assays made in the Laboratory on ores of copper, lead, manganese, and on coal.
Fossil bones in the Godavari alluvium.
Fossils from the Yenangyaung oilfield, Burma.
Assays of Raniganj coals.
Titaniferous iron-ore smelted in native furnaces.
Discovery of Thenardite at Didwana.
Discovery of Cancrinite in Kishengarh.
Pyrrhotite from the Kirána hills, Punjab.
Vivianite in the alluvium of Bengal.
Recent or sub-recent marine bed in Calcutta.
Pleistocene fossils from the Ganges alluvium.
A new form of blue Amphibole from Central India.
An unusual occurrence of common salt.
Assays of coal and coke from the Jherria and Raniganj fields.

Review of Mineral Production.

15. As a bye-product obtained during the course of reorganizing the office records with regard to the progress of mineral developments in India, material was obtained for the preparation of a Review of Mineral Production, for which statistics have been prepared to cover the period since the last issue of a Review by the Reporter on Economic Products to the Government of India. The new Review, covering the six years 1898—1903, is ready for issue to-day as part 1 of Volume XXXII of the *Records*, and, in accordance with the orders of Government, such reviews will be issued in future for every five years.

Memoirs.

16. Besides the papers issued with the *Records*, the following *Memoirs* have been published since April 1903:—

Report on the Jammu Coal-fields, by R. R. Simpson, B.Sc., *Memoirs*, vol. XXXII, part 4.

Note on the Sandhills of Clifton near Karachi, by R. D. Oldham, F.G.S., *Memoirs*, vol. XXXIV, part 3.

The diurnal variation in frequency of the Aftershocks of the Great Earthquake of 12th June 1897, by R. D. Oldham, F.G.S., *Memoirs*, vol. XXXV, part 2.

The Seismic phenomena in British India and their connection with its Geology, by Count F. de Montessus de Ballore, *Memoirs*, vol. XXXV, part 3.

The Geology of Spiti, by H. H. Hayden, B.A., B.E., F.G.S., *Memoirs*, vol. XXXVI, part 1.

The Permian fossils of the Central Himalayas, by Professor C. Diener, *Palæontologia Indica*, series XV, vol. I, part 5.

The Jurassic fauna of the Central Himalayas, by Professor V. Uhlig, *Palæontologia Indica*, series XV, vol. IV, part 1.

The Trigoniæ of Kach, by F. L. Kitchin, M.A., Ph.D., *Palæontologia Indica*, series IX, vol. III, part 2.

Imperial Gazetteer.

17. A considerable portion of the officers' time during the year has been taken up by the preparation of separate articles on the Geology of each of the Provinces, Agencies, States, and Districts of India for the new edition of the Imperial Gazetteer.

MUSEUM AND LABORATORY.

Determinative Work.

18. Mr. E. Vredenburg has been in charge of the Museum and Laboratory throughout the whole period under report, and, through his energy and extensive knowledge of the variety of subjects necessarily dealt with at head-quarters, as well as through the untiring energy of Mr. T. R. Blyth, the Assistant Curator, we have been able to deal, with a fair measure of success, with the great increase which has occurred in the work. The number of specimens sent in for determination and report amounted to 917 during the period under report, but this does not include, of course, the collections made by officers of the Department, or the samples sent by them for determination, and, as an officer in the field sends in only specimens which offer special difficulties, this part of the Curator's work forms a serious fraction of his total duties. For the ten years previous to 1903, the specimens so received from extra-departmental sources averaged only 94 a year. As Curator for much of that period I can gauge the serious additional task which has thus recently been thrown on the Curator, whom we have all been compelled to assist, with, however, the knowledge that desirable lines of research have had to be neglected, and desirable improvements in the Museum

have had to be postponed in consequence of the pressure of urgent current duties.

Training of Research Scholars.

19. To a certain degree the extra work done in the Laboratory has been accomplished by the introduction of carefully selected students who have shown an aptitude for chemical and petrological determinative work. One student holding a research scholarship from the Bengal Government has completed a course of training, combining the field and laboratory work, with very satisfactory results; one was deputed by the Gwalior Durbar, and another at his own expense came from Madras, both in special ways having shown the advantages of the training received, and both can be regarded as having returned by assistance the trouble taken in their training.

Chemical Work.

20. It is quite evident, however, in view of the lines of profitable investigation which we have had to avoid, and in view of the recently increased importance of the rarer elements in mineralogy, that the want of a special chemist, pure and simple, in charge of the Laboratory has now become a serious consideration, which, in the interests of practical efficiency, must soon be faced. A certain amount of work on material of a specially difficult kind is being undertaken by scientific friends abroad, such as that in connection with the peculiar rocks and minerals of the Vizagapatam hill-tracts, now being investigated by Professor T. L. Walker of Toronto University, formerly Assistant Superintendent in this Department. But most of the cases of interest, or, at any rate, cases which can be turned to full account only through chemical aid, require investigation before the officers leave the areas in which petrological and mineralogical puzzles are met, and special provision for such work at headquarters is urgently needed.

Meteorites.

21. Several new meteorites, obtained by donation or exchange, have been added to the collection during the past year. Amongst the most important additions is a superb mounted specimen of the Cañon Diablo meteoric iron, presented by Professor H. A. Ward of Chicago. The most interesting amongst the new meteorites is that which was seen to fall as a bright meteor to the east-north-east of Calcutta on the 22nd of October 1903. In falling, the meteor broke into several pieces, of which fifteen aerolites have been obtained for the Geological Survey Museum. The largest of these pieces weighed 1,538 grammes, and, like the smaller fragments,

was completely invested with a crust, which showed that fusion of the surface occurred during flight after disruption of the meteor. Fragments were found as widely separated as 7½ miles, aligned about east-north-east—west-south-west along a band crossing one of the branches of the Ganges near Kolapara (23° 28′ ; 90° 17′) in the Dacca district.

Donations.

22. Amongst the large number of donations made to the Museum during the period under report, the following specimens are of special value and interest:—Emeralds from Columbia and Norway, presented by Mr. Isaac Shrager; sodalite and garnet from Kishengarh, presented by Rao Syam Sunderlal Bahadur, C.I.E.; gadolinite and tin-stone from Palanpur, presented by Babu Baidyanath Saha, M.A.; samples of the new mineral thorianite and of thorite, presented by Mr. W. D. Holland, Ceylon; thenardite from the Didwana salt-lake, presented by the Commissioner of Northern India Salt Revenue; two aërolites which fell in the Dacca district on 22nd October 1903, presented by Raja Srinath Roy; and a large number of specimens of marbles from various States, including specimens from Baroda, Jodhpur, Kishengarh, Nimkhera, and Kharwa.

Ornamental Building Stone.

23. In addition to the fine collection of marbles which has now been made, representative specimens have been obtained of other varieties of stone used in the famous ancient buildings of India, and a summary of our knowledge concerning the distribution of the chief ornamental building stone, with which India is so conspicuously endowed, has been prepared by the Director, and published by the Trustees of the Victoria Memorial.

LIBRARY.

24. The additions to the Library during the period 1st April 1903 to 31st December 1904 amounted to 4,789 volumes, compared with 2,017 volumes in 1902-03. Of the books received this year, 2,988 were acquired as presentations from other institutions and authors, as against 1,184 volumes so obtained in 1902-03.

PALÆONTOLOGICAL WORK.

Descriptive Work in Europe.

25. The list of publications given above (paragraph 16) indicates the palæontological work which has been done on behalf of the Department in Europe. Professors Diener and Uhlig of Vienna have continued to

give their valuable help, and, besides the work done by Mr. A. C. Seward, F.R.S., and Dr. A. Smith Woodward, F.R.S., referred to below (paragraph 80), the description of fossils recently collected in Upper Burma has been undertaken by Miss Healey of Oxford and Mr. F. R. Cowper Reed of Cambridge, the last-named authority having just completed an exhaustive memoir on the Lower Palæozoic fossils of the Northern Shan States.

Head-quarters' Work.

26. Considerable progress has been made by Messrs. Pilgrim and Tipper in the registration and sorting of the large collections of fossils accumulated at head-quarters, and Mr. Pilgrim has made a number of determinations of fossils obtained during the year from localities of special interest. These include Cretaceous fossils collected by Mr. G. B. Reynolds in Persia (*Rec. Geol. Surv. Ind.*, XXXI, 45), Tertiary fossils obtained by Mr. L. G. Boyde in the Yenangyoung oilfield of Burma (*Rec. Geol. Surv. Ind.*, XXXI, 103), and a number of Permo-Carboniferous fossils obtained in Kashgar by Herr H. Keidel, the descriptions of which have been withheld out of deference to a specialist in Europe, who, it was found afterwards, had undertaken to describe Herr Keidel's main collections. Two other instances deserve more complete notice, both being interesting additions to the older pleistocene alluvium of the Indo-Gangetic plain and the Peninsula, including species of several extinct mammals, as well as remains of *Hippopotamus* now no longer living in India.

Pleistocene Fossil-bones in the Godavari alluvium.

27. Our attention was directed to the first of these two finds by Mr. H. F. G. Beale of the Public Works Department, and Mr. Pilgrim was deputed at once to excavate the fossil bones, which were exposed in the Godavari river-bed near Nandur Madmeshwar, Nasik district.

Mr. Pilgrim succeeded in excavating the cranium of a remarkably large specimen of *Elephas namadicus*, together with portions of a femur and the pelvic bones. In the gravels near the same spot he found a single tooth of *Equus namadicus*, some crocodile teeth, several species of recent molluscs, and the lower jaw of *Hippopotamus palæindicus*, which was afterwards stolen. In a special paper, to be published in the *Records*, Mr. Pilgrim has given a full description of the bones found, has discussed the evidences on which these beds are grouped with the pleistocene deposits in the Narbada valley, and has pointed out the wide distribution of *Elephas antiquus*, of which

E. namadicus is a variety, indicating the eastward migration of the forms from an European centre of distribution.

Pleistocene Fossils in the Gangetic alluvium.

28. The second instance of this kind was discovered by Mr. R. R. Gales of the Public Works Department, whilst sinking wells for the foundations of the new railway bridge across the Ganges at Allahabad. The fossils were found embedded in a calcareous conglomerate 80 to 100 feet below low-water mark, and 120 feet below the surface of the banks in the river. On examination by Mr. Pilgrim they were found to include remains of *Bos namadicus*, associated with remains of *Hippopotamus*, *Elephas*, *Cervus* and *Bubalus*, thus adding another instance to the occurrences of pleistocene deposits below the recent alluvium of the Indo-Gangetic plain. From the advanced type of structure shown by the specimens of *Bos namadicus*, which was the only form that could be identified specifically, it is concluded that these deposits below the present Ganges, like those described by Dr. Falconer in 1830 below the Jumna, are slightly younger than the pleistocene deposits of the Narbada valley (*Rec. Geol. Surv. Ind.*, XXXI, 176).

Oyster-bed in Calcutta.

29. The discovery in July last of an old oyster-bed in Calcutta at a level well above present high-tide mark shows that, besides the general depression which has occurred to permit of the accumulation of alluvial deposits in the Gangetic delta, there have been oscillations also of the relative level of sea and land during recent geological times (*Rec. Geol. Surv. Ind.*, XXXI, 174).

SEISMOLOGY.

30. Two papers dealing with earthquake phenomena have been issued since the last report, forming parts 2 and 3 of volume XXXV of the *Memoirs*. The first of these two, by Mr. R. D. Oldham, dealing with the "diurnal variation in frequency of the aftershocks of the great earthquake of 12th June 1897," gives a detailed discussion of the questions raised by the same author in a paper read before the Asiatic Society of Bengal.[1] It had previously been pointed out by Mr. Oldham, that any effect which the attraction of the sun and moon may have in determining the occurrence of a shock will be found most probably at or about the times when the tidal stresses reach their

[1] On tidal periodicity in the earthquakes of Assam. *Journ. As. Soc. Ben.*, LXXI, 1902, 139—153.

maximum; as these times vary with the latitude of the place of observation and the declination of the attracting body, the effect will be obscured if earthquakes are grouped merely by their time of occurrence, irrespective of the variation in the time when the tidal stresses reach their maximum. Treated on these lines, the discussion of the record of aftershocks shows that there seems to be a distinct tendency to an increase in frequency about the time when the horizontal tidal stress is varying most rapidly in amount and direction, and a decrease in frequency at the times when it is changing most slowly. The vertical stresses appear to be practically without influence.

31. The Count de Montessus de Ballore, who has made a special study of seismology, courteously offered the results, published in the second memoir,[1] of his enumeration of earthquake occurrences in India, showing the greater frequency of shocks in the areas most recently subjected to geotectonic movements.

ECONOMIC ENQUIRIES.

Coal.

Jammu:
Mr. R. D. Oldham.
Mr. R. R. Simpson.

32. Mr. R. R. Simpson has made a detailed examination of the Tertiary coal-seams in the Jammu State, forming the fields known as Ladda, Sangarmarg, Mehowgala, Siro valley, Kalakot, and Lodhra, the results of his investigations being published as a special memoir (*Memoirs*, vol. XXXII, part 4, 1904). The work was commenced in March 1903 with a conference on the ground between Messrs. R. D. Oldham, R. R. Simpson, and E. L. Hope of the Dandot Colliery, the investigation being afterwards carried on by Mr. Simpson alone.

The value of the coal in this area has recently been forced into prominence by a revival of the old project for building a railway to connect the city of Jammu with Srinagar, one intention being to arrange the alignment so as to tap the coal-bearing area in the Jammu hills.

The coal in all cases is extremely friable, due to crushing by earth-movements, and generally has a high percentage of ash; it sometimes exhibits coking qualities, and, on account of the pyrites it contains, is

[1] The Seismic Phenomena in British India, and their connection with its Geology. *Mem. Geol. Surv. Ind.*, XXXV, part 3, 1904.

in some places liable to spontaneous combustion. The quality of the material is subject to great variation in different fields, that from the Anji valley, Sangarmarg and Lodhra being little better than carbonaceous shale. Locomotive trials made on briquettes of Ladda coal gave satisfactory calorific results, but difficulties were experienced on account of the insufficient strength of the briquettes—difficulties which might possibly be avoided by improvements in the system of their manufacture.

The following estimates of the workable coal in the Ladda field were made as the result of extensive prospecting operations:—In the areas from which coal might be brought to a railway with a terminus at the foot of the Ladda slope, the yield would be 795,029 tons for the Ladda slope itself, and for the Sukhal gully a *probable* addition of 696,383 tons, with a *possible* further amount of 613,730 tons. The area from which coal might be brought to a railway aligned along the Anji valley, was estimated to yield 1,657,117 tons. In this field, therefore, the total yield of coal might amount to just 3¾ million tons. For the other fields the results were so unsatisfactory that the working of the coal on a large scale was considered to be out of the question.

The washed and briquetted Ladda coal was considered, as the result of several analyses and trials, to be probably as valuable as average Bengal coal, but the cost of mining would be so heavy, when taking into account also the loss of coal through washing and the additional unusual charges due to briquetting and transport to Tawi station, that it could not compete with coal brought from Bengal, and the proposal to undertake the exploitation of these coal-fields is thus regarded, at present rates, to be distinctly unpromising.

Mohpani: *Mr. R. R. Simpson.*

33. Mr. R. R. Simpson was deputed, during March 1904, to inspect the Mohpani colliery, in order to advise the Government with reference to the proposed transfer of the property from the Nerbudda Coal and Iron Company to the Great Indian Peninsula Railway Company. A detailed report of the investigation was forwarded to Government.

Northern Shan States: *Mr. P. N. Datta.* *Mr. R. R. Simpson.*

34. Mr. Datta surveyed the boundaries of the Lashio coalfield during the course of his mapping in the Northern Shan States, and, at the end of the season 1903-04, paid a short visit to the Namma coalfield, where he discovered some new seams of coal, of which one seam

was some 10—12 feet thick, with, however, a coal containing an undesirably high percentage of moisture. Mr. Simpson, who is now making a detailed examination of these fields, has partly exposed the thick seam found by Mr. Datta, and so far has found it to be quite 14 feet thick. The work, commenced with the current field season, has not yet progressed sufficiently to permit of drawing any definite conclusions with regard to the value of these coal deposits.

Coke-making.

35. The publication of Mr. T. H. Ward's paper on the feasibility of introducing recovery ovens for the manufacture of coke (*Rec. Geol. Surv. Ind.*, XXXI, 92) has led to further tests of Bengal coal and distinctly favourable estimates as to their suitability for the recovery of bye-products, for which arrangements are now well developed.

Engineering Questions.

Ceylon mountain railway: *Mr. C. S. Middlemiss.*

36. During the period under report the advice of the Department has been requested on several occasions in connection with engineering problems directly depending on the nature of local geological formations. Towards the end of April 1903 the services Mr. C. S. Middlemiss were lent to the Ceylon Government to join a committee appointed to deal with the questions of tunnelling and landslips on the hill railway.

Tungabhadra, Penner, Karmnassa, and Ramtek irrigation projects.

37. At the end of the last field season Mr. Middlemiss was deputed to report on the site selected for a proposed dam across the Tungabhadra river near Hospet. Mr. Simpson was similarly deputed to examine the proposed site for a large dam across the Penner river in the Nellore district. In January 1904 the Director made a report for the Bengal Government on the site suggested for the formation of a large irrigation reservoir in the Karmnassa valley on the Kaimur range; and in November a similar investigation was carried out on behalf of the Central Provinces Administration in connection with the proposed dam across the Sur river, near Ramtek, Nagpur district.

Himalayan Stations.

38. In connection with the Himalayan stations special inspections and reports were made by the Director—(1) with regard to the effect of the railway cuttings on the hill-slopes below the new Civil Secretariat buildings in Simla, (2) on the site of the jail and some of the higher slopes in Dharmsala,

and (3) on two occasions in Darjeeling, first in connection with the training works in the cutcherry jhora and on the Rungaroon road, and, second, to give an opinion on a claim for damages alleged to have been accelerated in the lower part of the station in consequence of drainage changes introduced on the recommendation of the Landslips Committee of 1899.

Gold.

Upper Assam: *Mr. J. M. Maclaren.*

39. During the last field season Mr. J. M. Maclaren made a survey of the auriferous gravels in Upper Assam, and, in spite of the natural difficulties of the country, managed to make a very thorough exploration of the area. The results of Mr. Maclaren's examination of the river gravels have been published in a special paper,[1] in which he has summarized the history of previous investigations in this area.

40. The most striking result in connection with the work is, perhaps, the universal distribution of the gold in extremely small percentages throughout the river gravels. This wide distribution is considered to be due chiefly to the wandering of the Brahmaputra river over the plain, and to the extensive development of the Tipam sandstones, which are auriferous in places, and are now undergoing erosion.

41. The gold of the recent gravels and of the older Tipam sandstones is probably obtained originally from the quartz veins of the crystalline schists in the Miju ranges beyond the Brahmakhund. From the presence of gold in the Assam valley above the mouth of the Dihong, and from the negative evidence as to the occurrence of gold in the Tibetan Tsangpo, it is regarded as extremely improbable that the Tibetan plateau furnished any of the gold now found in Assam.

42. The gold is generally most abundant in the beaches at the ends of long pools in the rivers, especially when high banks are being eroded, and in the longitudinal boulder beaches to which the gold is carried by the back eddies, whilst the fine-grained, homogeneous masses of sand are quite barren.

43. The most prominent spots noticed were, (1) the Guri Mara, above Sadiya and opposite the Chunpara stockade, (2) the Sibia Mukh on the Dihong river, and (3) the Derpai pool of the Subansiri river. Of these the deposit in the Subansiri river was considered to be the one

[1] The Auriferous Occurrences of Assam. *Rec. Geol. Surv. Ind.*, XXXI, 205-232 (1904).

most worth prospecting, with a view to exploitation by dredging operations, for which Mr. Maclaren has outlined the chief difficulties likely to be met, and the line of operations offering the fewest chances of failure.

44. The Assam river gravels, like those known to be auriferous in Peninsular India, have the serious drawback of being completely disturbed every year by the floods of the monsoon. For the concentration of gold a comparatively equable current is essential—a condition rarely obtainable in the rivers of India, for these are almost dry in the cold weather and roaring torrents in the rains.

45. It is to be regretted that the race of Sonwals, who formerly flourished by washing for gold in Upper Assam, have almost completely disappeared, being tempted, under recent changes in the system of administration and other industrial developments in the province, to forsake their ancestral calling. In the interests of those who may be found later to undertake the work of gold recovery on a large scale, it is desirable that the native worker should be encouraged: the amount of gold he recovers from the gravel is insignificant compared to the value of his information to the prospector and investor.

Laterite.

Aluminous Laterites.

46. The stages by which we have arrived at the conclusion, that the peculiar weather-product known as laterite, so commonly found in moist, tropical countries, often shows the essential constitutional characters of bauxite, were summarised in a special paper published in the *Geological Magazine* in February 1903.[1] Since that paper was published, Dr. H. Warth, late Deputy Superintendent of the Geological Survey, has continued the interesting line of research which he pioneered, by recently showing that the weather products of a basaltic rock exposed to the temperate climate of England differ essentially from those of the similar Deccan trap in the Bombay Presidency.[2]

47. The questions raised by the results of these researches have a two-fold interest to the owners of lands in the humid parts of the tropics: (1) the origin of laterite explains some or all of the occurrences

[1] Holland. On the constitution, origin, and dehydration of Laterite. *Geol. Mag.*, decade IV, vol X, p. 59.

[2] H. Warth. Weathered Dolerite of Rowly Regis compared with the Laterite of the Western Ghâts near Bombay. *Geol. Mag.*, decade V, vol. II, 21st January 1905.

of bauxite, and raises the interesting questions naturally suggested by the remarkable differences between the chemical products of weathering in temperate and tropical climates; (2) the fact that bauxite must always be the main, and up to the present practically the only, source of the metal aluminium, indicates a possible value for laterite not hitherto suspected. It is not without interest in this connection to observe that the original bauxite of Les Baux in the south of France was first worked without success as a source of iron, just as many laterites in India have been employed by the native iron-smelters, and, on account of their commonly rusty colour, have been regarded as essentially ferruginous products, without raising the suspicion that many contain large proportions of alumina in the form of free hydrates, available for separation as soluble alkaline aluminates.

48. The high percentage of alumina in an Indian laterite was first remarked by Mr. F. R. Mallet, late Superintendent of the Geological Survey, in a paper on the iron-ores and subsidiary materials for the manufacture of iron in the Jabalpur district,[1] whilst in 1903 Dr. H. Warth published the results of a number of analyses of Indian laterites showing a variation in alumina percentage up to 67·88 per cent.[2]

49. In April 1903, Mr. H. H. Hayden was deputed to South India to examine some of the promising occurrences of laterite in the Madras Presidency; and it was intended to extend this work to other parts of the Peninsula where aluminous laterites were known or suspected to occur, but the investigation was interrupted by Mr. Hayden's deputation with the Tibetan expedition in the following September (paragraph 85). Other officers, however, whose survey work necessarily took them across lateritic areas, were instructed to pay special attention to any considerable deposits showing the characters generally displayed by the aluminous varieties of laterite. Mr. Middlemiss made a special study of the occurrences in the Vizagapatam hill-tracts; Mr. Fermor collected specimens from the highly aluminous deposits in the Central Provinces, some of which were examined also by myself, whilst Mr. La Touche took advantage of an opportunity during the last Puja holidays to sample the laterites of Nalhati in Bengal. The result has been the definite determination of a number of instances in which the

[1] F. R. Mallet. *Rec. Geol. Surv. Ind.*, vol. XVI, 1883, 113.

[2] H. and F. J. Warth. The composition of Indian Laterite. *Geol. Mag.*, decade IV, vol. X, 154, April 1903.

percentage of alumina is as high as in the high-grade bauxites mined as sources of alumina in Europe and America, and the material appears to exist in quantities altogether out of proportion to the present consumption of the mineral.

Vizagapatam hill-tracts.

50. In the Vizagapatam hill-tracts Mr. Middlemiss paid especial attention to the high-level laterites of the Kalahandi State, and his observations tended to confirm, in his opinion, the conclusions drawn from an examination last year of the adjoining estate of Jeypore.[1] Mr. Middlemiss found in both areas that the higher hills rising above 4,000 feet are never capped by laterite, and that the latter occurs as deposits, in places 80 to 100 feet thick, limited to a very well marked plane surface, 3,500 to 4,000 feet above sea-level. This surface, he considers, on account of its uniformity and extent, to have originated as a plain of marine denudation, on which the laterite was subsequently formed, and which was afterwards modified by the ordinary erosive action of subaerial agencies of denudation.

51. The upper layers of these high level laterites show the usually hardened, variegated, vesicular, and tubular characters, whilst the lower layers are of the more homogeneous and uniformly coloured, light-red, soft and earthy material. Although these high-level deposits may be found as far south as Yendriki hill (18°12′; 82°38′) and Ontali hill (18°1′; 82°40′), or even further south on a few high ridges, the area over which they are mainly developed stretches from the neighbourhood of Korlapat (19°41′; 83°12′) in Kalahandi to the hills north of Doliamb (18°39′; 82°56′) on the Jeypore-Vizianagram road. Viewed from some prominent hill to the east of the main watershed, for example, Niamgiri, 4,973 feet (19°34′; 83°29′), or from the plateau south-west of Girliguma (19°7′; 82°55′), this assemblage of closely approximating laterite-caps gives the impression of a vast and almost continuous plain existing at the present day; but this impression is nevertheless deceptive, for in those parts where the laterite is most widely spread its area is small compared to that of the uncovered rock. That these disconnected outliers of laterite were, however, once parts of a continuous bed, which has, with the crystalline rock below, been since deeply eroded, is considered by Mr. Middlemiss to be a justifiable conclusion.

[1] General Report for 1902-03, p. 25, para. 63.

Central Provinces.

52. The deposits hitherto referred to as laterite in the Balaghat and Jubbulpore districts cannot be regarded as normal, recent weather-products; they agree much more perfectly with the ordinary bauxites of Europe in petrological characters; they often show well-defined bedding, and are disturbed in a way which, in Peninsular India, we have learned to regard as evidence of considerable geological age. They certainly are not products of any superficial process now in operation in that region, and we look forward to their economic development as an opportunity of displaying evidence which will add materially to our knowledge of the past physical history of this area.

Prospects of economic development.

53. With the establishment of the fact that high-grade aluminous laterites, or bauxites, do exist in India, the work of prospecting and exploitation of the most promising areas may be left appropriately to private enterprise. But there are certain aspects of the problem, which, in view of the haste being shown in securing concessions, it appears desirable to point out for the assistance of prospectors. The low average values of bauxites at European and American ports makes it unlikely that simple export of the raw material will be remunerative, except possibly in the case of some remarkably rich forms which have been found; and to extract the alumina, either for export as such, or for use locally in the manufacture of the metal, will require a supply of alkali, which, however, can be partially recovered after the separation of alumina from the alkaline aluminate, and its cost, consequently, should not be any serious handicap to the suggested industry. The whole problem is, however, now open to private enterprise, and so far as we can judge, after the preliminary investigations which have been carried out, the economic prospects are no less promising than the theoretical questions awaiting solution.

Manganese.

Central Provinces: *Mr. L. L. Fermor.*

54. In consequence of the rapid expansion of manganese-ore mining, and the growing importance of the industry, an officer of the Department was reserved last year for an examination of the manganese-ore deposits, with a view to the preparation of a special memoir along the lines adopted two years ago in the case of mica. Mr. L. L. Fermor was selected for this work, and during the field season 1903-04

completed the first section of his task by a study of the occurrences in the Central Provinces, his survey covering the districts of Nagpur, Chhindwara, Bhandara, Balaghat, Mandla, Seoni, and Jubbulpore.

55. Mr. Fermor's progress report for the season gives an elaborate account of the manganese-ores and of the crystalline rocks with which they occur, and although the relationships of the ore-bodies to the "country rock" are indicated, the theory of their ultimate origin is very properly withheld until the similar ores in other areas, being examined during the current field season, have been thoroughly studied.

56. Braunite is the predominating oxide of manganese in the ore-bodies which are being worked. The ore-bodies occur as lenticular masses lying in the ordinary gneisses, schists, and quartzites of presumably Archæan age, and as regards immediate origin appear to have been formed, at least partly, by the alteration of manganese silicates, amongst which spessartite, rhodonite, and manganese-pyroxenes are prominent species. Manganiferous silicates—piedmontite, spessartite, and mangan-hedenbergite—are found also in the crystalline limestones of the Nagpur and Chhindwara districts, and have been changed in some instances into oxides, which would be considered worth working but for the unlimited quantities of richer ore exposed in the same area.

57. Some of the manganese minerals found during the course of this survey, such as dialogite, spessartite, mangan-hedenbergite, and piedmontite, have not been recorded hitherto in India, whilst others are apparently species new to science. One of these new forms from the Nagpur district displays the essential family characters of the pyroxenes, but has a remarkable pleochroism of red, blue and lilac, whilst another pyroxenic form, found in the Chhindwara district, changes from a pink to a greenish-brown colour. In association with the deposits of Bhandara district, a crimson manganiferous mica was found with characters apparently novel amongst the mica family, whilst specimens of a blue amphibole, obtained from the deposits in the Jhabua State, Central India, have been described by Mr. Fermor as a new variety of the amphibole family (*Rec. Geol. Surv. Ind.*, XXXI, 235).

58. In the four districts grouped together near the eastern edge of the Deccan Trap—Nagpur, Chhindwara, Bhandara, and Balaghat—Mr. Fermor obtained detailed descriptions of over 60 deposits of manganese ore, most of which contain valuable material, rich enough and pure enough to command a price sufficient to cover the cost of mining and of transport to the European and American markets. Although

the higher grades only are being exported, the large amounts which have been quarried have made no serious impression on the total stocks in sight, and for the time being the removal of the valuable mineral from the country, at rates which return less than half its market value, may be regarded with a complacency which will be less tolerable when steel manufacture in India reaches a stage comparable to the growing requirements of the country. The statistics with regard to the trade in manganese-ores have been reviewed in a special paper published to-day.[1]

Silicification of Rocks.

59. An interesting feature in connection with the area in which the manganese ore-bodies lie is the extensive silicification which has occurred amongst many of the Archæan crystalline rocks, as well as in the infra-trappean Lameta beds. This effect is probably directly connected with the action of the great Deccan trap-flows, which have but recently been removed by erosion and cut back to their present position near Nagpur. We are not at present prepared to connect these phenomena with the removal of silica from the manganese silicates from which the oxide ores have apparently been formed, but it is at least significant that our most valuable ore-bodies—in the Central Provinces, in Jhabua, and the recently discovered deposits in Belgaum—are all near the edge of the trap formation. We have, however, no present evidence to show the former extension of the trap as far east as the Vizianagram area, where manganese ores occur under conditions apparently similar to those of the Central Provinces.

Salt.

Sambhar Lake: *The Director.*

60. The first stage has been completed of a special enquiry into the condition of the large salt lake at Sambhar in Rajputana. The questions of the origin of the salt and of the prospective resources of the Lake were raised by Mr. R. M. Dane, C.I.E., Commissioner of Northern India Salt Revenue, in 1901, in consequence of the general impression then developing as to the depreciation in quality of, and the increased difficulty of obtaining, salt at Sambhar. A very accurate map of the lake was made by the Survey Department, and a report was submitted in 1902 by Dr. F. Noetling of the Geological Survey, who suggested a

[1] T. H. Holland: Review of the Mineral Production of India. *Rec. Geol. Surv. Ind.*, XXXII, p. 55.

theory for the origin of the salt, and pointed out the necessity of exploring the lake-bed by borings in order to finally settle this question.

Arrangements were made in 1903 for the boring operations, the sites being determined by the Director, in consultation with the Commissioner of Salt, in December 1903, and the work was commenced in March 1904. Three borings—one near Sambhar at the eastern end of the Lake, one at the so-called *khasana* near the centre, and one off Nawa in the west—passed through the silt, and touched the underlying Aravalli schists at depths of 61, 70, and 76 feet, respectively. At the same time, samples of the silt were obtained at various points at depths of 4, 8, and 12 feet, in order to determine by analysis the amount of salt stored in the upper layers.

61. A report, now in course of preparation, gives the full details of evidence from which it is concluded that the salt resources of Sambhar are limited to the body of silt filling-in the depression in the Aravalli schists, where the sodium chloride, along with large quantities of sodium sulphate and sodium carbonate, has accumulated in a way common to arid regions of internal drainage.

62. In the lake-brine formed by the absorption of the salts from the silt, the ratio of chloride to other soda salts is now about 86 : 14, and, judging by the few analyses recorded, this represents a distinct depreciation in the quality of the lake-brine, in which the ratio of chloride to other soda salts in 1869 was 90·9 : 9·1. As a similar result is shown by analyses of the subterranean brines and of the lake-mud, it appears to be certain that the artificial removal of a little over 4 million tons of salt during the past 34 years has appreciably diminished the richness of the lake in chloride, although there has been but a microscopic inroad made into the enormous stores of salt lying in the silt. A preliminary estimate gives the present amount of salt in the upper 12 feet of the silt as just a million tons per square mile.

63. The present system of manufacture consists of the simple solar evaporation of the compound brine until, by separation of the excess of chloride, a point is reached at which the solution is nearly saturated by the sulphate, which is the next most abundant salt. The manufacture is then stopped, the salt being removed for sale and the bitterns being returned to the lake. On account of the rapid increase in the solubility of the sulphate between 0° C. (32° F.) and 33° C. (91° F.) with, at the same time, a small and, for practical purposes, unimportant, variation in

the solubility of the chloride, the saturation point for the sulphate is reached much sooner when the brine is cold than when it is warm. On this account it is possible to extract a larger proportion of the chloride in the hot weather than in the cold season, whilst, on account of the diurnal variation in temperature, a brine will precipitate sulphate in the night and redissolve the whole or part of it in the heat of the day. These facts have been observed in a general way by the experienced manufacture officers, but there is room for the introduction of greater precision in the present system of removing the simple chloride, and it is to be hoped that a still more important step will be taken by making a practical test of a scheme which I have suggested for the circulation of the brines and bitterns amongst the kyars, for the purpose of first removing the excess of chloride, and then, by treatment of the bitterns in the cold season, of removing the sulphate. As the sulphate is much less soluble than the chloride at low temperatures and much more soluble than the chloride in the hot weather, a judicious system of alternation of crops, such as should be possible under the natural great ranges of temperature at Sambhar, will permit of the removal of both instead of only a small fraction of one of the sodium salts. At present there appears to be a prospect, in the opinion of the salt officers, of such a system being practicable, and if it prove to be possible under the natural conditions at Sambhar, as it certainly is when the temperature can be controlled artificially, the result will be the indefinite extension of manufacturing operations for the more important chloride, as the bitterns will thus be prevented from returning to the Lake, and so fouling the reserves of brine.

64. By the present system of manufacture the separation of the clean chloride stops at a point when, according to the temperature, from 10 to 40 per cent. only of the salt has been extracted, and as the only available supplies are probably those in the uppermost layers of the silt, of which only the sandy portions readily yield their salts to the inflowing fresh water, the economic life of Sambhar would, under existing conditions of manufacture, come to an end long before an appreciable inroad had been made into the total reserves in the lake mud.

65. For the continued success of the system of manufacture, either that now observed, which results in yearly depreciation of the lake-brine, or the proposed modification, which, if practicable, will indefinitely lengthen the term of operations, a full supply of water is essential, and only a distinctly more important interest should be allowed to curtail the limited supplies now being obtained from the inflowing rivers.

Water.

66. As the outcome of orders issued by Government in consequence of the recommendation of the Irrigation Commission, numerous enquiries have been made for advice concerning the prospects of obtaining artesian water: these include enquiries by the Bombay Government with regard to Gujarat; by the Madras Government with regard to Chingleput; by the Bengal Government with regard to Muzaffarpur; by the Burma Government with regard to the districts of Myingyan, Yamethin, and Meiktila; by the Punjab Government with regard to the Mianwali district and the neighbourhood of Dera Ghazi Khan; by the Assam Administration with regard to the Silchar area; by the Central Provinces Administration with regard to the Damoh district; and by the Agents to the Governor General in Baluchistan, Rajputana, and the North-West Frontier Province.

GEOLOGICAL SURVEYS.

Assam.

Upper Assam: *Mr. J. M. Maclaren.*

67. During the course of his survey of the river-gravels in Upper Assam, with special regard to their auriferous characters, Mr. Maclaren found opportunities for studying some of the geological features of the country, of which our information hitherto had been but fragmentary. Observations were made on most of the formations, representing a material advance on our previous knowledge, the whole subject being summarized in a special paper published in the *Records*, illustrated by a geological map.[1]

68. The interesting discovery of Permo-Carboniferous marine fossils in the Subansiri river is referred to in another paragraph (83). These fossils are at present being described by Professor Diener, of the Vienna University, whose preliminary examination of them has confirmed Mr. Maclaren's field determination of their general affinities.

Disang series.

69. Examination of the unfossiliferous shales and sandstones previously distinguished as the Disang series appears to indicate, though much of the evidence is of a negative character, that they are of older Tertiary age, but, from their

[1] Vol. XXXI, pp. 179—204.

general resemblance to certain rocks in the Mikir hills, they are considered to be post-Nummulitic.

Coal-bearing formation.

70. An addition has been made to the previously known development of the valuable Tertiary coal-bearing series by their discovery in the Manbhum range, a long spur parallel to the Noa Dihing, and running out from the Miju Mishmi country into the plains as far as the Tengapani.

Tipam sandstones.

71. The question of the age of the Tipam sandstones has been advanced by the extension of a practically unbroken series of observations from the area in which they are typically developed, round the head of the Assam valley, to the Sub-Himalayan sandstones of the normal Siwalik type of Upper Tertiary age.

Geotectonic problems.

72. The fascinating problems in geotectonic geology presented by the Upper Assam valley (where two opposed systems of folds—the Himalayan arc on one side and the Malayan arc on the other—are separated by a wedge of crystalline rocks, forming what Mr. Maclaren conveniently terms the Miju ranges) have been summarized with characteristic charm in Professor Suess' chapter on the "Syntaxis of the mountains of India."[1] But Mr. Maclaren's observations, exceeding in precision those made by workers who have hitherto been able to make only isolated observations in limited parts of this area, have shown that the reversed dips in the two opposed systems of folds do not truly justify the conclusion that the valley between is cut out along a simple anticlinal axis: the dips are the results of the overfolds produced by tangential pressure from opposite directions acting on separate systems of rocks, which are kept apart further east by the immovable mass forming the Miju ranges. The Patkais form the northern termination of the Malayan arc, and they, as well as the Himalayas, which end also with the head of the Assam valley, are distinct, orographically and geologically, from the great meridional mountain system of Upper Burma, Tibet, and Western China.

Bombay.

Nasik district: *Mr. G. E. Pilgrim.*

73. Whilst in the Nasik district in connection with the excavation of fossil bones in the Upper Godavari, Mr. Pilgrim took the opportunity of examining the Deccan Traps, with the object in view of discri-

[1] Das Antlitz der Erde, 1892, Chapter VII.

minating between the different lava-flows, in a selected section over 900 feet thick, displayed on the hill face to the north-east of the reservoir at Igatpuri. The specimens collected have been registered and stored in the Museum in view of further work in adjoining areas at a future date.

Burma.

Northern Shan States: *Mr. P. N. Datta.*

74. Mr. P. N. Datta continued the mapping of unsurveyed ground in the Northern Shan States, and covered the area represented by standard sheets Nos. 377 and 378, together with the eastern portion of sheet 331, the south-west corner of sheet 432, and north-west part of 433. Much of this area was occupied by the groups of rocks previously reported, the old classification being followed pending the revision now under consideration and awaiting the results of palæontological work being done in England. Collections of fossils and rock-specimens were made, and notes were recorded of the few minerals exposed of possible economic value. The only mineral of special importance is the coal occurring in the Lashio and Namma basins, referred to in another paragraph (paragraph 34).

Kashmir and Tibet.

Kashmir: *Mr. R. D. Oldham.*

75. During the summer of 1903 Mr. Oldham was engaged on a survey of parts of south-east Kashmir. The principal results of interest obtained have been published in two separate papers in the *Records*, one dealing with a number of outcrops of the Permo-Carboniferous Zewan beds in the Vihi district, and the other containing an account of the glaciation and physical history of the Sind valley.

The Zewan beds.

76. In connection with the Zewan beds Mr. Oldham has pointed out that their apparent conformable superposition on the volcanic series, hitherto regarded as real, is probably deceptive, and as evidence of unconformity he calls attention to the great variation in development of the shaly bottom beds of the Zewan stage, and the abrupt cessation of the volcanic rocks on every section.

Sind valley.

77. Near Sonamarg Mr. Oldham found a fine series of lateral and terminal moraines pointing up the valley of the Sind, and, after further exploration of the

valley, he found the peculiar position of these to be due to a great reversal of drainage. At the time of the formation of these moraines the waters from the hills round Sonamarg must have escaped northwards through the valley now forming the Zoji-la. As the date of the formation of the Sonamarg moraines seems to coincide with the latest and least extension of the glaciers, the Sind valley must have captured the head-waters of the adjoining Gumber, and so extended its course by about 20 miles. This also involves an elevation, within quite recent times, of the range through which the Zoji-la runs by at east 2,500 feet relatively to the next range to the south of Sonamarg.

Karewa deposits.

78. Mr. Oldham found several opportunities for examining the *karewa* deposits in the Kashmir valley, and came to the conclusion that the old idea of their lacustrine origin needs revision.[1] The complete absence of laminated shales, the limited extent of bedding when sufficiently distinct to be recognizable as such, the common occurrence of coarse sands, and fragmentary state of the fossil shells, indicate that lacustrine conditions could not have been any more thoroughly developed when these deposits were formed than at the present time.

Khunmu beds.

79. In the General Report for 1902-03 (page 22) I referred to the discovery by Dr. F. Noetling of plant and vertebrate remains in beds reported to occur below Productus limestones in a conformable series of strata near Khunmu, south-east of Srinagar. These fossils have now been critically examined by Mr. A. C. Seward, F.R.S., and Dr. A. Smith Woodward, F.R.S., through whose courtesy we are able to publish full descriptions in a forthcoming part of the *Palæontologia Indica*.

80. The plant remains prove to be several more or less imperfect fronds of a new species of *Gangamopteris*, for which Mr. Seward proposes the name *G. kashmirensis*, together with a single fragment of a leaf doubtfully referred to Schimper's genus *Psygmophyllum*. The evidence, so far as it goes, is in favour of assigning the Khunmu beds in Kashmir to a position at least as low as the Talchirs. The vertebrates, described by Dr. Smith Woodward, include remains of fishes and of a labyrinthodont, the former being referable to two new species of *Amblypterus*, whilst the latter is a new species of *Archegosaurus*, all having near relatives amongst the Lower Permian or the Carboniferous rocks of Europe.

[1] Manual of the Geology of India, 2nd Ed., 1893, 420.

81. The plant and vertebrate bearing beds of Khunmu were first reported by Dr. Noetling to be seen lying below the Productus limestone in a conformable series of strata, but subsequent examination of the ground by Mr. R. D. Oldham (whose observations have since been confirmed by Mr. J. A. Cunningham) showed that no beds of any sort actually rest on the plant-bearing series, that the Productus limestones are half a mile off, and that the area is too highly disturbed to accept the approximate parallelism of the two series alone as evidence of any order of stratigraphical superposition. We must, therefore, regretfully fall back on the few fossils which have been found as our only grounds for assuming the Palæozoic age of the beds. The testimony of the plants does not, naturally, alter the state of the Gondwana problem, for *Gangamopteris* in Kashmir has the same significance as *Gangamopteris* in Hindustan. The fish remains, however, afford independent confirmation of the Palæozoic age of the beds, and give us our first direct support for the accepted age of the Lower Gondwana system. It is possible, and, judging by the fossils, even probable that the plant-bearing beds are stratigraphically below the Productus limestone; it is to be hoped that further field work will show the stratigraphical relationship of the two; but, meanwhile, we have to be content with the unsupported testimony of the fossils, the probable stratigraphical order having been prematurely reported as an observed fact.

The Northern coast line of Gondwana-land.

82. The geography of the old Gondwana continent, on which the great fluviatile formations were laid down, is a subject no less interesting than the question of geological age of the older strata, and during the past year observations have been made which have added materially to the precision of the ideas so ably summarised in Professor Suess' great work *Das Antlitz der Erde.*

83. In north-east Assam Mr. J. M. Maclaren has made an important discovery of Permo-Carboniferous marine fossils at a point not far from the previously known Lower Gondwana strata of the Dikrang valley, and although the specimens were not obtained from beds *in situ*, there is no doubt, from the lithological characters of the boulders, that they could not have travelled for any great distances.[1]

84. We may assume, therefore, that the beds in Kashmir at one

[1] J. M. Maclaren. The Geology of Upper Assam. *Rec. Geol. Sur. Ind.*, XXXI, 1904, 186, 187.

end of the Himalayan range, and those in Assam at the other end, indicate roughly two points on the northern coast-line of Gondwana land. The observations made by Mr. H. H. Hayden during the past year have contributed still further towards the solution of this problem, for he has found that, immediately to the north of the crystalline masses of Sikkim, there is a great basin of fossiliferous strata, with a general east-west strike, forming without doubt the south-eastward extension of the well-known fossiliferous zone of Garhwal and Spiti far away to the north-west, where the fossiliferous beds lie also on the northern flanks of the great central crystalline zone of the Himalayan range. There is thus little doubt that the crystalline axis of the Himalayas has been a long persistent landmark in the physical history of Central Asia, marking approximately the northern boundary line of the great Gondwana continent, and forming the southern shore of the old Eurasian ocean to which Professor Suess has given the name *Tethys*.

Southern Tibet: *Mr. H. H. Hayden.*

85. The observations with regard to the geology of Southern Tibet were made by Mr. H. H. Hayden during the progress of the recent mission to Lhasa under Colonel Sir F. E. Younghusband, K.C.I.E., who has called my attention to the untiring energy displayed by Mr. Hayden in taking advantage of the necessarily limited opportunities for work in a hostile country of a physically difficult character. His results are, however, of an importance and interest which, when published in full, will merit the appreciation of the scientific world.

86. The crystalline complex forming the chief part of the State of Sikkim has been recently described by Professor E. J. Garwood in an appendix to Mr. Douglas Freshfield's "Round Kangchenjunga," and references will be found in that work to Sir Joseph Hooker's glimpse in 1849 of the fossiliferous zone forming the unknown land to the north in Tibet, and of Dr. W. T. Blanford's exploration as far as the northern borders of Sikkim in 1870.

Sedimentary zone of Southern Tibet.

87. The Tibetan zone to the north of the Sikkim boundary is composed of a variety of sedimentary formations, often metamorphosed but occasionally highly fossiliferous, and represents the lower Tertiary, Cretaceous, Jurassic, probably Trias and possibly some of the Palæozoic systems. The east-west trend of the crystalline zone prevails equally in the sedimentary rocks, the component

beds of which strike parallel to the Himalayas and dip as a rule to the north; but in parts of the zone, especially at and around Gyantse, intense folding has occurred, with consequent metamorphism, reducing the local rocks (in this case of Jurassic age), almost to a series of crystalline schists.

88. The only beds, which can with any show of probability be referred to the Palæozoic group, are a series of slates and schistose limestones found along the north-eastern border of the crystalline zone in the Khongbu valley, between Phari and Sikkim: they are cut off by faults from all the other sedimentary formations, and, in the absence of fossils, there is no means of determining their age. A thick series of limestone, slate, and quartzite, found in the hills to the south of the Phari plain, may represent the Triassic and probably also the lower Jurassic systems. They are sparsely fossiliferous in their upper beds.

With these two exceptions, the whole of the sedimentary zone is composed of beds of younger Mesozoic age, with great intrusive masses of granite and basic igneous rocks: the former is most conspicuous in the valleys of the Tsang-po and Kyi Chhu and in the immediate neighbourhood of Lhasa, and the latter at Gyantse and along the shores of Yamdok Tso.

89. Beyond the northern frontier of Sikkim a broad zone of Jurassic slate, quartzite and shale, striking east-west, extends for several miles to the north, its upper boundary being defined approximately by a line running through Tinki, Khamba dzong and Tuna. A subordinate band of limestone included in these slates about 8 miles to the south of Khamba dzong has yielded a number of well-preserved fossils, which include cephalopods, brachiopods and lamellibranchs of middle Jurassic (dogger) age. Immediately south of Khamba dzong the familiar Spiti shales can be recognised by their characteristic fossils, which here, however, are, as a rule, only fragmentary.

90. To the north of the Jurassic boundary, a series of parallel east-west ridges stands out conspicuously above the rolling downs of shale: these ridges are formed chiefly of limestone, and almost certainly comprise the whole of the Cretaceous system, and the eocene stage of the Tertiary. Fossils characteristic of the cenomanian and turonian stages occur towards the middle of the series, and include *Turrilites costatus*, Lam., below and *Hippurites* sp. and *Radiolites* sp. above. The highest beds found consist of Tertiary sandstone overlying Nummulitic limestone: between these a thick series of fossiliferous limestone, with

subordinate sandstones, probably includes the uppermost Cretaceous and oldest Tertiary.

91. These beds extend for only a comparatively short distance to the north and soon give place again to an endless succession of more or less metamorphosed slate and sandstone, extending far to the north beyond the Tsang-po and almost, if not quite, up to the southern shores of Tengri Nur. Fossils are rare, but have been found at several localities, and indicate that the whole of this vast series, with the exception of some limestones found in the hills to the west and north of Lhasa—which may be of Cretaceous age—belongs to the Jurassic system.

Age of the unfossiliferous systems in the Lower Himalayas.

92. The fossiliferous character of the strata lying on the northern (Tibetan) flanks of the crystalline axis stands in remarkable contrast to the unfossiliferous character of the beds which form the southern or Lower Himalayan zone. The persistence of the northern fossiliferous zone eastwards as far as Sikkim, now established, naturally accentuates this contrast, and increases the suspicion, which has recently been growing amongst the members of the Geological Survey, that the Lower Himalayan rocks, like those of Simla, Kumaon, and Bhutan, are members of very ancient systems of sediments, all or in part pre-Cambrian, nothing other, in fact, than northerly extensions of the Vindhyan, Cuddapah, and similar old systems on the Peninsula, which have been caught, like the much younger Gondwana beds of Darjeeling and Assam, in the great earth-folds that have produced the Himalayan range. That one, two or more stratigraphical stages on the south could be unfossiliferous whilst their equivalents on the north are fossiliferous might be possible; that such an accident could be carried through every geological epoch from Cambrian to Cretaceous is so highly unlikely, that we are driven to regard the ingenious and elaborate systems of lithological correspondences, which have been propounded to distribute the strata of the Lower Himalayan zone over the standard fossiliferous scale, as so much misdirected, though well intended, mental energy.

Madras.

Vizagapatam Hill-tracts: *Mr. C. S. Middlemiss.*

93. In November 1903 Mr. Middlemiss continued his work in the Vizagapatam hill-tracts, taking the extreme northern and southern areas for exploration. The northern parts were finally linked up with

Mr. Smith's work in Ganjam and with Dr. Walker's in Kalahandi State, whilst the southern parts were similarly linked with Dr. King's work in the Rajahmundry area. The main rocks forming the solid geology of the former area proved to be a mere continuation in this direction of the Archæan rock systems (khondalites, charnockites, and gneissose granite) already described further to the south. They occur in a monotonous series of bands of one or the other rock in dreary repetition. Towards the south, in the direction of the Godavari river, through the Rampa Agency and the northern parts of the Godavari district, the same remarks hold good with regard to the Archæan systems. No further examples were found of either the elaeolite-syenite gneiss or the sapphirine-bearing rocks. It was incidentally established that some of the old local varieties of gneiss named by Dr. King, such as the Kailassa and Bezwada gneiss, are variations of the khondalite series. On comparing King's Bezwada gneiss (distinguished by containing murchisonite) with some of the khondalite series in the gorge of the Godavari, the two were found to be identical; but the crystals and bands of murchisonite are regarded as adventitious in the ordinary khondalite, and probably due to injection of pegmatitic intrusions or contemporaneous veins. The Kailassa gneiss is simply typical khondalite.

Gondwana beds, Godavari District: *Mr. C. S. Middlemiss.*

94. During the latter part of the field-season Mr. Middlemiss was engaged on some questions in connection with the Gondwana strata near Rajahmundry, in consequence of some alleged discoveries of the coal-bearing series in positions not in accordance with the geological map. A number of plant remains found in the purple sandstones and shales at Gudigudiem (17° 9′; 81° 35′) proved to be identical with, or nearly related to, those described as of Golapilli age from near Ellore.[1] The original mapping of the ground at this point is, therefore, vindicated by fossil evidence. A certain number of minor instances were recorded towards the revision of Dr. King's original survey in other parts of the area; but, subject to the results of proposed boring operations, there appears to be no reason for modifying the accepted ideas concerning the structure of the ground as inferred from the official geological map.

95. On the left bank of the Godavari between the Deccan Trap escarpment (north-north-east of Rajahmundry) and Korukondah (17° 10′; 81°53′), in addition to the crystalline schists, marked on

[1] Pal. Ind., series II, vol. I, 163 (1877).

Dr. King's map, evidence was found, in road-metal pits, of purple sandstones representing one of the upper Gondwana stages. A small upstanding hill, east-south-east of Raghudavapuram (17° 10′; 81° 46′), is composed of the same formation. This shows that the Upper Gondwanas persist on the left bank of the Godavari, and are probably connected by a series of such outcrops, generally hidden by the recent alluvium, with the patches of Upper Gondwanas further east at Juggumpett (17° 10′; 82° 7′).

Rajputana.

Elæolite and Sodalite Syenites, Kishengarh: *The Director, Mr. E. Vredenburg.*

96. One of the most interesting results obtained during the year was the discovery of a new series of the remarkable family of elæolite-syenites near Kishengarh in Rajputana. Our attention was first directed to these rocks by the receipt of specimens of blue sodalite sent in mistake for corundum. On subsequent examination of the ground by Mr Vredenburg, the intrusions of elæolite-syenite were discovered, together with a variety of sodalite, presenting characters, so far unexplained, and unique amongst minerals (*Rec. Geol. Surv. Ind.*, XXXI, 43). When freshly broken, the patches of sodalite are carmine in colour and the fresh rock face gives the appearance of being splashed with blood, but in daylight the colour rapidly, and in direct sunlight almost suddenly, disappears. Many of the specimens when kept in the dark for a few months recover their carmine colour, losing it again on exposure to either daylight or to electric light. The sodalite does not, so far as we can find, differ in chemical composition from the ordinary varieties of the mineral, and neither the loss nor the recovery of colour is affected by the humidity of the atmosphere. Specimens have been sent to Europe for more critical examination, but no explanation of the remarkable phenomenon has so far been offered, and although the recovery of colour has not occurred in some specimens after short intervals of concealment in the dark, there is now no doubt, after the numbers of instances which have been examined by various observers, that both the disappearance and the reappearance of the carmine colour are real and regularly recurring phenomena.

In the course of a geological reconnaissance of the Kishengarh State made by Babu Baidyanath Shaha, M.A., as part of his work as a research scholar, an extension of the elæolite-syenites was found to

the north-north-east of Kishengarh, and with it the mineral cancrinite was found for the first time in India.

CONCLUSION.

97. It is dangerous in any branch of natural history to assess the ultimate scientific value of an established conclusion, or to arrange the results of observations in any order of merit, and consequently, within the usual limits of this Report, it has been possible to review only those of our past year's results whose importance and proximate bearing on current problems are at present manifest. There are possibly many more important observations recorded in the special papers published during the year in the *Records* and *Memoirs* of the Department, but the discovery referred to in the last paragraph, the work which has been done in Kashmir, Tibet, and Assam, and the additions to our knowledge of the older alluvial deposits, can be safely selected as advances of unusual scientific interest. In economic work, besides the results selected for special mention in this Report, the Department has kept in touch with the numerous developments of private enterprise, and I think it is not rash to say that the prospects of a healthy development of the mineral resources of India are now more favourable than they have ever been. Besides the continued progress in the development of those minerals which are described in the Review of Mineral Production as minerals raised for consumption by direct processes and for export, there has been the definite determination of the essential conditions for the utilization of raw products which enter into the web of industrial enterprises far more important to a civilized community than gold and precious stones. The recent discoveries of aluminous ores and the demonstration of the existence of iron-ores in quantity and richness sufficient to counterbalance the heavy assembly costs of other raw materials required to manufacture iron and steel, will create the conditions necessary for the utilization of our enormous supplies of coal, and for the development of bye-products which will insure the gradual increase in the production of those materials for which India is at present dependent on foreign countries.

T. H. HOLLAND, *Director,*
Geological Survey of India.

CALCUTTA:
The 2nd January, 1905.

PRELIMINARY NOTE ON THE GEOLOGY OF THE PROVINCES OF TSANG AND Ü IN TIBET.

BY H. H. HAYDEN, B.A., B.E., F.G.S., *Superintendent, Geological Survey of India.* (With Plate 7.)

THE despatch of the recent British Mission to Tibet, under Colonel Sir F. E. Younghusband, K.C.I.E., afforded an invaluable opportunity for geological exploration in the little-known provinces of Tsang and Ü, which lie to the north of Sikkim and Bhutan. With the exception of the work of Sir Joseph Hooker[1] and of Dr. Blanford[2] along the north-eastern, and of Professor E. J. Garwood[3] on the north-western, borders of Sikkim, our knowledge of the geology of these two provinces was confined to a few scattered observations to be found in the writings of Captain Turner and subsequent travellers, and little or nothing was known of the great extent of country lying between the northern frontier of Sikkim and Tengri Nur lake.

Area mapped.

The greater part of the area visited during the recent expedition lies between the meridians 88° and 91° E. and the parallels 28° and 30° N.; much of this area, as well as the Chumbi Valley has now been surveyed, geological mapping having been carried on concurrently with the topographical survey, and I am greatly indebted to Captain C. H. D. Ryder, R.E., who was in charge of the Survey party, for his kindness in providing me with tracings of his work as it progressed.

Sikkim crystalline rocks.

The geology of the greater part of Sikkim is already fairly well known, and my traverse through that State was too rapid to afford opportunities of making any appreciable additions to the observations of previous writers. To the north of Gangtok, the prevailing rock is gneiss, which is for the greater part merely a foliated granite, but includes also beds of sedimentary origin, represented by quartzite, schists, slate, and crystalline limestone.

[1] Himalayan Journals.

[2] Journ. As. Soc. Bengal, 1871, p. 367.

[3] Round Kangchenjunga, by D. W. Freshfield (1903). Appendix by Prof. E.J. Garwood, M.A., F.G.S.

On the right bank of the Tista, at a short distance above Tung, the limestone is a grey and white banded marble of great beauty: quartzite and white crystalline limestone also occur in both the Lachen and Lachung valleys at a few miles above Chungtáng. These beds, however, are of no great extent, the prevailing rock up to the Tibetan frontier being granite, usually more or less foliated. Between Lamteng and Tangu, white marble, similar to that near Chungtáng, occurs in some quantity, with pyroxene-scapolite granulite and a graphitic biotite-sillimanite gneiss. To the north of Tangu, granite and gneiss continue up to the frontier, where they pass through schists into quartzites, conglomerates, and slates of Mesozoic age.

Boundary between crystalline and younger sedimentary zones.

The boundary between the crystalline rocks and the younger sedimentary beds has a general east-west trend, following the line of high peaks, which constitutes the line of greatest altitudes of the eastern Himalayas. This line includes the peaks of Pauhanri, Kangchenjhau, and Chumiumo, all of which consist of crystalline rocks, the boundary of the sedimentaries running along their northern slopes. Similar conditions prevail throughout the Himalayas of Sikkim, Chumbi, and Bhután, all the highest peaks being composed of the more resisting crystalline rocks, while the lower hills to the north are composed of softer sedimentary beds of limestone, slate, and sandstone.

Chumbi valley crystallines.

As has already been pointed out by Professor Garwood, much of the so-called gneiss of Sikkim consists of foliated granite, and the same applies to the rocks of the Chumbi valley, which are merely the easterly continuation of those of Sikkim and consist chiefly of gneiss—in large part a foliated granite—with schists, quartzites, and some limestone. Throughout the valley of the Ammo Chhu, the prevailing rock is a coarse granite, which forms the steep, forest-clad hills on either side of the river, but at Dothák, about 20 miles above the village of Chumbi, the crystalline rocks are suddenly replaced by beds of limestone, quartzite, and slate. Granite and gneiss are again found to the north of Phari, forming the mountain of Chumolhari, and the greater part of the snowy range running northwards from that peak and separating Bhután from Tibet.

Palæozoic (?) rocks.

Although the greater part of the area surveyed during the recent expedition is covered by sedimentary rocks, there is a rather disappointing monotony in their

character. It was hoped that some continuation of the beds, from which the Permian and Triassic exotic blocks of northern Kumaon are derived, might be found between the Himálayas and Lhásá, but with the exception of a small area in the Khongbu valley, between Phári and eastern Sikkim, no beds older than Mesozoic were found anywhere north of the crystalline zone. The small area referred to lies round Tálung in the Khongbu valley, and consists of schists, phyllites, and altered limestones. The rocks are highly metamorphosed and quite unlike any of the Mesozoic rocks found near Phári or to the north of Sikkim: it seems probable that they may represent some of the Palæozoic systems, but the apparent absence of fossils leaves their age uncertain.

Trias (?).

To the east of these supposed Palæozoic beds, and separated from them by a fault, is a thick series of limestone with subordinate bands of quartzite and slate, well seen in the hills east of Dothák and again on the Pemo Lá, between Phári and Bhután. On the south it is in abrupt contact with the Chumbi granite, by which the various beds have been considerably metamorphosed. There are apparently no fossils in the lower beds, any that there may have been originally having now been destroyed by the metamorphism: a badly preserved cast of an ammonite, possibly *Danubites* sp., but quite undeterminable, was found in a flaggy quartzite near the middle of the series above Dothák. The same series continues along the hills between the south-western edge of the Phári plain and Bhután, and probably forms the peak of Masongchungdong. At about 5 miles to the south south-west of Phári, the highest beds of the series are limestones, which contain a few badly preserved brachiopods resembling Jurassic forms: these are overlain by slates and quartzites of undoubtedly Jurassic age. It is therefore probable that the Dothák beds include part at least of the Triassic system, but whether they include older beds also it is impossible to say, since any fossils that they may have contained have now been obliterated by the metamorphism that they have undergone, and no beds older than Jurassic have been found in any other locality.

Jurassic system. Lower beds.

By far the most extensive system met with is the Jurassic, which covers almost the whole area lying between the Himálayas and Lhásá, and extends far to the north into the hill-ranges separating the Pembu valley from the basin of Tengri Nur. In spite of its great extent, it has

yielded but little of interest, for the whole area has suffered so severely from metamorphism that the rocks consist chiefly of crushed and altered slate and limestone, with quartzite and calc-schist. In northern Sikkim and in the neighbourhood of Phári, the Jurassics are found in contact with the crystalline zone and have been locally metamorphosed by the granite of Chumolhari and neighbouring peaks. The lowest beds, which appear to belong to that system, are the limestones already mentioned as occurring to the south-south-west of Phári: these are overlain by an endless succession of slate and quartzite—or, in less disturbed localities, shale and sandstone—with occasional beds of conglomerate. Fossils are very scarce in the lower part of the series, and have been found only in a few localities: they include an impression of an ammonite in the slates and some brachiopods in the quartzite: the latter were found on the south side of the Kangra La, below Me-do, and include a specimen of *Rhynchonella* sp.

Middle Jurassic limestones.

Above the slate and quartzite, at Mekhyi-gunru,—about 8 miles south of Khámbá dzong—a band of limestone, about 50 feet thick, contains a large fauna: the fossils are well preserved and include cephalopods, brachiopods, and lamellibranchs. One of the commonest species is *Trigonia costata*, Sow., which occurs in large numbers in the lower beds of the limestone. Ammonites and belemnites occur in some quantity, and a large *Nautilus* is fairly common. The brachiopods include chiefly species of *Rhynchonella* and *Terebratula*: the commonest genera of lamellibranchs are *Trigonia* and *Ostrea* or *Alectryonia*. The fossils have not yet been determined, but the presence of *Trigonia costata* indicates that the age of the limestone is middle Jurassic. The strike of the beds is east-west, but the whole area has been greatly disturbed and the limestones were found only in this one locality: they may possibly occur again between Phári and Tüna, but, if so, they are hidden by the moraine material which covers the Tang La and the Tüna plain.

Spiti shales.

The limestones are overlain by a belt of dark shale, which extends from the flanks of Chumolhari on the east, to the northern Nepal frontier on the west, and covers the greater part of the plain surrounding Khámbá dzong: these are the representatives of the Spiti shales, and contain concretions enclosing fragments of the ammonites characteristic of that stage in other parts of the Himalayas. Immediately behind Khámbá dzong, and at Tüna, they are overlain by shales, limestones, and sandstones,

probably representing the whole of the Cretaceous system, with a small band of lower Tertiary rocks. The Cretaceous beds extend from Khámbá dzong to Tüna in a comparatively narrow strip, resting on the Jurassics. From their northern boundary again Jurassic slates and shales extend in an endless succession of comparatively low ranges far to the north beyond the Tsangpo.

Cretaceous system.

The Cretaceous beds consist of shales and flaggy limestones below, followed by brown shales with concretions; these are overlain by grey shales passing up into massive limestones, overlain by sandstone and again limestone and calcareous shale. The lowest beds have yielded no fossils, but the concretions near the top of the brown shales contain ammonites (*Acanthoceras* sp.) and *Turrilites costatus*, Lam.; this horizon therefore belongs to the cenomanian stage of Europe. The overlying grey shales contain, near their base, large numbers of *Gryphæa* sp., and, higher up, a few well-preserved echinoids, chiefly species of *Hemiaster*, resembling *H. cenomanensis*, Cot. The shales pass up into a thick limestone series, consisting of three bands of limestone, each about 100 feet thick separated by shaly limestone and shale. The lowest bed is sparsely fossiliferous, and the fossils, chiefly echinoids, are poorly preserved and in most cases not determinable. The overlying shales contain a few badly-preserved lamellibranchs. The two upper limestone bands, with their intermediate shales, contain great numbers of *Rudistæ*, chiefly *Radiolites*, sp. *Foraminifera* occur more or less throughout the whole limestone series, but are much more numerous in the upper beds, in which they form bands of foraminiferal limestone, overlying the Radiolites beds: the commonest genera are *Orbitoides* and *Orbitolites*. The Rudistæ limestones pass up into thin-bedded arenaceous limestone with corals and lamellibranchs: the corals include species of *Cyclolites*, with *C. regularis*, Leymerie; among the lamellibranchs *Hinnites* is very common. Echinoids also occur, though as a rule badly preserved: the genus *Hemipneustes*, however, has been recognised.

The coral limestone is overlain by a thick bed of coarse, gritty sandstone, often highly ferruginous and containing in places small masses of hæmatite and limonite, but apparently no fossils beyond worm-tracks.

The fossils collected from the above series have not yet been worked out, but a few could be readily identified and indicate that the whole of the Cretaceous system is represented between the Spiti shales

and the top of the ferruginous sandstone. The lower flaggy limestone and brown shales overlying the Spiti shales, have not yielded any fossils, but the concretionary bands at the top of the brown shales contain cenomanian cephalopods, and the echinoids of the overlying grey shales are probably also of cenomanian age. The lower, massive limestones and the Rudistæ limestones may represent the turonian, and possibly in part the senonian, stages of Europe, while the overlying coral limestone, with *Cyclolites regularis*, *Hemipneustes* sp., and *Hinnites* ? sp. (cf. *H. foliaceus*, Noetling) should probably be referred to the upper senonian. The overlying sandstone may therefore represent the danian stage.

Tertiary system.

The sandstone is overlain by massive limestone containing large numbers of gastropods. Near the base of the limestone is a band composed largely of *Orbitoides* sp., and somewhat higher up a specimen of *Nautilus*, resembling *N. sublævigatus*, d'Orb., was found in a bed with a few gastropods. The remainder of the limestone contains chiefly gastropods and some echinoids, all very badly preserved ; the former include species of *Ovula*, *Phasianella*, *Conus*, and *Oliva*. Until the fossils have been worked out, the age of this limestone must remain doubtful, but its stratigraphical position certainly points to a Tertiary age, and it has therefore been included provisionally in that system. It is overlain by shaly and nodular limestone full of *Foraminifera*, but containing also a few *Nautili* and large numbers of *Velates schmideliana*, Chemn. This foraminiferal limestone passes up into calcareous shale containing lamellibranchs—including *Spondylus* sp.—and overlain by nummulitic limestone.

Above the nummulitic limestone there is a small thickness of dark micaceous shale and flaggy sandstone, with calcareous bands containing gastropods and bivalves.

The above Tertiary series is well exposed in the valley behind Khámbá dzong, on either side of the stream flowing west from the Dzongbuk Lá. The beds dip to the north, and the uppermost shales are seen at about one-third of the way up the ridge on the right (north) side of the valley. Here they are cut off by a fault which runs more or less parallel to their strike, and throws them in some places below the lower Tertiary foraminiferal limestone, in others below the Rudistæ limestone. No younger Tertiary rocks were found in the neighbourhood of Khámbá dzong, or at Tüna, but they may very

possibly occur in the hills to the west of Guru, where Cretaceous and Tertiary beds can be seen from the ridge north of Tüna; but owing to political considerations, that area could not be visited and could not therefore be mapped in detail.

Fossils of Jurassic slates.

As will be seen from the map, the outcrop of the Cretaceous and Tertiary beds is comparatively narrow; near Do-chen they give place to Jurassic rocks, which extend beyond the Tsangpo and probably almost to Tengri Nur. These are in places interrupted by granite, as between Kángmá and Gyántse and again in the valleys of the Tsangpo and Kyi Chhu; they are everywhere crushed and folded, and are often intersected by dykes of basic igneous rock. Fossils are exceedingly rare and in almost all cases very poorly preserved: they have been found in only five localities, *viz.*, 3 miles north of Do-chen (*Gryphæa* sp.), in the hills above—east of—Mangtsa (*Gryphæa* sp., and casts of *Spiriferina* sp.), Kángmá (crinoids), on a hill 3 miles east of Gyántse (*Perisphinctes* sp.), and in the valley of the Rálung Chhu, between Gubshi and Lungma (*Perisphinctes* sp., belemnites and brachiopods). Of these, the least badly preserved are the belemnites, which occur in black shales, with brachiopods, at Gorchi and Sálákhang; these beds probably represent the Spiti shales and can be followed for many miles, forming the higher parts of the hills between the Rálung Chhu and the Yung Lá.

The only ammonites found in the Spiti shales were obtained near Khámbá dzong, where they form the nuclei of concretions; they are as a rule only fragmentary.

Great extent of Jurassics.

How far the Jurassics extend to the north it is impossible to say, but they have been traced up to Penam dzong, in the Nyang Chhu, whence they are almost certainly continuous up to and beyond the Tsangpo; thence they are apparently continuous to Cháksám on the Tsangpo, and though interrupted by granite intrusions, appear to extend over the greater part of the ranges to the west of the Kyi Chhu valley up to Lhásá, although the Kyi Chhu itself has cut its course along a mass of intrusive granite. Above Lhásá, again, they appear to extend for many miles to the eastward, and certainly occur again at about 7 miles to the north of Lhásá, where they form the higher parts of the range separating the Kyi Chhu from the Pembu valley. To the north of Pembu they can be seen extending far into the hill-ranges separating that valley

from the Tengri Nur basin, where Cretaceous rocks are know to occur, and although, on the higher ridges, they may be capped by younger beds, they probably cover the greater part of the intervening country.

Although no well-preserved ammonites have been found in the Spiti shales in the area visited during the recent expedition, beautiful specimens are, nevertheless, frequently to be found in Tibetan houses, being employed, it is said, in certain religious rites. Those seen by me were said by the Tibetans to have been brought from certain black hills near Shikar dzong, and similar fossils are said to be found also further to the west. It is probable, therefore, that a zone of Jurassic rocks extends from at least as far east as the 91st meridian, along the north of Nepal to Hundes, and the excellent state of preservation of the specimens said to have come from near Shikar dzong points to the probability that the rocks in that area are comparatively little disturbed.

Former glacial conditions.

The uplands to the north of Sikkim and Bhután furnish abundant evidence of the former greater extent of glacial conditions in the trans-Himalayan region. This is seen in the old moraines, erratics, old lake-basins, and the many other phenomena indicative of former glacial action. Throughout the plain of the Yáru river, around Khámbá dzong, characteristic *roches moutonnées* show the direction of flow of old glaciers from the northern slopes of the Himalayas: at the same time erratic blocks of granite which are stranded on the hills, now at a height of several hundred feet above the surrounding plain, and which were probably derived from Kangchenjhau and its neighbourhood, prove that the drainage from that area must at one time have had a northerly trend, and that consequently the Lachen river has captured much of what was formerly the watershed between the north and south systems of drainage, while even the Yaru plain and valley itself, which now drains into Nepal, has probably been captured from the northern system by the gradual encroachments of the southward-flowing streams.

On the northern flanks of Chumolhari, too, old moraines extend for many miles beyond the limits of the now comparatively insignificant glaciers, into the Tüna plain.

Of the lakes, both Kala Tso and Yamdok Tso apparently owe their existence to the damming up of old river valleys by fans from side valleys, and the consequent formation of an area of closed drainage,

That both lakes have shrunk since their formation is proved by the existence of old terraces at some height above the present levels of the lakes, whilst, at the same time, the waters of both are slightly, though distinctly, brackish.

Igneous Rocks.

Both acid and basic igneous rocks are found in this part of Tibet.

Granite of Sikkim and Chumbi.

The former are represented by granite, which forms the greater part of the main range of the Himálayas of Sikkim, Chumbi, and Bhután. It is found again among the snowy peaks to the north of the Karo Lá, in the valley of the Tsangpo between Shigatse and Cháksám, and throughout the valley of the Kyi Chhu up to Lhásá. The Himálayan granite, as seen in Sikkim and Chumbi, is either a foliated biotite granite ("gneiss") or a fresh schörl granite—usually occurring in the form of pegmatite. The presence of hornblende has also been recorded by Professor Garwood.[1]

Granite of peaks north of Karo La.

The granite of the peaks to the north of the Karo La was not seen *in situ*, but blocks were found on the plain to the north of Rálung and in the streams draining the northern slopes of the Karo Lá group of snowy peaks.

Tsangpo and Kyi Chhu granite.

The granite of the Tsangpo and the Kyi Chhu forms a wide belt following the valleys of those two rivers, which appear to have found less difficulty in cutting their way through this rock than through the Jurassic slates and quartzites, which now form the adjoining hills. This might seem, at first sight, somewhat anomalous, but the explanation would appear to lie in the wide diurnal range of temperature, which has a more powerful disintegrating effect on a coarse and heterogeneous rock like the Kyi Chhu granite, than on the softer, but more compact and homogeneous, slates, rendering the former friable and easily eroded, while having comparatively little effect on the latter.

The Tsangpo and Kyi Chhu rock differs from the Himálayan granite in containing large quantities of hornblende and sphene. At Nam, on the Kyi Chhu, about 20 miles below Lhásá, the granite is a very handsome porphyritic variety with large crystals of flesh-coloured orthoclase.

[1] *op. cit.* p. 289. But Professor Garwood does not state whether he regards the hornblende-bearing variety as a granite or as a gneiss of sedimentary origin.

In the neighbourhood of Lhásá, the rock is more compact, but otherwise similar in mineralogical character; in places it is a comparatively fine-grained, grey rock which is largely used for building purposes.

Syenite.

At Chaksam ferry, a large hill-mass on the right bank of the river is composed of a greenish-grey rock, approaching syenite, and undoubtedly related to the granites, seen on the opposite bank of the river, from which it differs only in the larger proportion of plagioclase (oligoclase) and of ferro-magnesian silicates which it contains.

Dolerite.

The basic rocks occur as dykes and sills in the Jurassic slates, and are most conspicuous in the neighbourhood of Gyantse and round the shores of Yamdok Tso. They are chiefly fine-grained rocks of doleritic type, but include also

Serpentine.

serpentines. The latter occur in some quantity between Dongtse and Penam, in the valley of the Nyang Chhu, and are probably responsible for the native reports of the occurrence of coal in that valley. At a little distance and in certain lights, they appear black and shiny, and might easily be mistaken for that mineral, as indeed one native informed me that they had been.

Economic Geology.

Gold.

The area visited during the recent expedition is strikingly poor in minerals of economic value, the only one found *in situ* being gold, which was obtained in very small quantities from the coarse gravel beds of the Tsangpo; these were panned at various points near Cháksám, but the largest yield was only at the rate of ·28 grain of gold per ton of gravel. The concentrates, which were examined by my colleague, Mr. Maclaren, were found to contain, in addition to much magnetite and zircon, a small quantity of rutile, tourmaline, and hercynite, and probably uraninite.[1]

Coal.

Persistent rumours of the existence of coal at Lhásá, where it was said to be used in the local "arsenal," proved groundless; the local rocks consist chiefly of granite, Jurassic slate, and quartzite, with no trace of carbonaceous beds, while the fuel employed in the "arsenal" was charcoal.

[1] See note by Mr. Maclaren, on pages 171-172.

Some quantity of graphite was found in that building, being used for the manufacture of crucibles, and I am indebted to Mr. E. C. Wilton, C.M.G., Assistant to the British Commissioner, for samples of the mineral, and also for the suggestion that it represents the so-called "coal".

Graphite.

The graphite, Mr. Wilton tells me, is said to come from the Rong valley between Yamdok Tso and Shigatse. The same valley is also said to yield lead, but the report was not substantiated by any reliable evidence.

Lead.

While at Lhásá, I bought a number of samples of the gem-stones employed by the local jewellers; these included turquoise, ruby, tourmaline, emerald, and sapphire. The jewellers stated that all these stones were brought from considerable distances, the turquoise being obtained from Ládáki and Mongolian traders, the rubies and emeralds from India and Mongolia, and the sapphires from Ládák and India. I could obtain no reliable information as to the existence of any indigenous source of gems. The rubies and emeralds were small and very pale: the sapphires were, on the whole, of better quality, but small, often pale and flawed, and though a few stones of good colour were to be obtained, they were very small and of little value. Pink tourmaline is also apparently used largely, not being distinguished from ruby of similar colour. Yellow and white rock-crystal and red garnet are also used. It appears that, with the exception of turquoise, practically all the gem-stones used in Lhásá come from foreign countries, and it is not at all improbable that quite a large proportion of them come from Ceylon and Burma, *viâ* Calcutta and Nepal. In fact, no mineral industries of any kind appear to exist in the area visited by the Commission.

Gem-stones.

Before closing this note, I must record my very great indebtedness to Colonel Sir Frank Younghusband, K.C.I.E., not only for his unflagging interest in the work, but also for his assistance, so generously given at all times, and without which much of the exploration would have been impossible.

Summary.

1. The northern parts of Sikkim and Chumbi are composed chiefly of gneiss and granite. Some schists and crystalline limestones, found at Tálung in the Khongbu valley, may be of Palæozoic age.

2. A thick series of limestone, with subordinate beds of quartzite

and slate, occurring to the east of Dothák, probably includes at least a part of the Triassic system.

3. The greater part of the provinces of Tsang and Ü is covered by Jurassic rocks. The lower beds contain few fossils, but highly fossiliferous limestones of middle Jurassic age were found to the south of Khámbá dzong, and fossiliferous representatives of the Spiti shales occur at Khámbá dzong and in the hills to the east and south-east of Gyantse.

4. A comparatively narrow strip of Cretaceous and Tertiary rocks runs from Khámbá dzong to Tüna. The Cretaceous rocks are shales, limestones, and sandstones, and represent the whole of that system. The lowest fossiliferous horizon is of cenomanian age and contains *Turrilites costatus*, Lam. The turonian, and probably part of the senonian stage is represented by Rudistæ limestone, with *Radiolites* sp. The upper senonian is represented by limestone with *Cyclolites regularis*, Leymerie, *Hemipneustes* sp., and *Hinnites* sp. A thick bed of coarse, ferruginous sandstone may be of danian age.

5. The Tertiary system is represented by gastropod-bearing limestone, overlain by shaly foraminiferal limestone with *Velates schmideliana*, Chemn. This is followed by nummulitic limestone and shale. It is probable that none of these are younger than eocene.

6. Basic igneous rocks, including dolerite and serpentine, occur as dykes in the Jurassic slates near Gyantse and along the shores of Yamdok Tso. Granite is found in the valleys of the Tsangpo and Kyi Chhu and also at Lhásá, where it is used as a building stone. The Lhásá rock is a fairly coarse-grained, biotite granite, containing oligoclase, hornblende, and sphene.

7. Few minerals of economic value were found *in situ*; gold occurs in very small quantity in the Tsangpo gravels, and an efflorescence, composed largely of sodium carbonate, is found at Utsi, 6 miles north-west of Khámbá dzong.

Note by J. M. Maclaren, B.Sc., F.G.S., Geological Survey of India, on Auriferous Concentrates from Cháksám on the Tsangpo.

Two samples of concentrates were brought by Mr. H. H. Hayden, of this Department, from the Tsangpo, near Cháksám. No. 1 weighed 500 grains and was the result of washing 112 lbs. of gravel from the left bank of the river, one mile above Cháksám. 399 grains, or 80 per cent., of the concentrate, proved to be magnetite, while the greater

part of the remainder was composed of zircons. Of gold, there were only four extremely fine specks, far too fine to be weighable.

No. 2 sample, of 790 grains, was the result of washing 160 lbs. of gravel from the right bank of the Tsangpo above the Cháksám ferry. This contained 612 grains of magnetite sand, or 77 per cent., nearly the same as the preceding. The residue of 178 grains was carefully washed and yielded a number of extremely small grains of gold, weighing ·02 grain. The total gold content per ton of these gravels is ·28 grain, or a little more than $\frac{1}{4}$ grain, of a value of one half-penny.

The minerals associated with the gold are magnetite and zircon, making up, as already stated, nearly the whole of the concentrates. There are also occasional grains of rutile, of tourmaline, and of hercynite. With the gold, and impossible to separate from it by ordinary washing, there remained a little dust, which was resolved, under the high powers of the microscope, into black, cubical crystals with cubical cleavage. These, from their extremely high specific gravity, their crystalline form and their colour, are probably uraninite or pitchblende.

The washings were made at a wide portion of the river, and gold was obtained in the dish only when washing was carried on in the coarser gravels, the stones of which ranged up to 6 inches in diameter. There is no record of gold-washing along the Tsangpo, and the poverty of its gravels, as indicated by the above results, confirms previous assumptions that the gold of the Assam valley has not been derived from the Tibetan highlands. The extreme fineness of the gold, combined with its flaky character,—the largest grain is no more than ·3 mm. long and ·01 mm. thick—indicates a distant source, possibly as far distant as the gold-regions of the Manasarowar lakes.

Geographical Index.

	Latitude, N.	Longitude, E.
	° ′	° ′
Ammo Chhu	27 30	89
Chaksam	29 18	90 43
Chumbi	27 25	88 57
Chumiumo	28 2	88 35

	Latitude, N.	Longitude, E.
	° ′	° ′
Chumolhari	27 50	89 18
Chungtang	27 36	88 41
Do-chen	28 8	89 20
Dongtse	29 1	89 27
Dothák	27 37	89 6
Dzongbuk La	28 16	88 41
Gangtok	27 20	88 40
Gorchi	28 50	89 50
Gubshi	28 49	89 48
Guru	28 6	89 20
Gyantse	28 52	89 37
Kala Tso	28 18	89 26
Kangchenjhau	28	88 42
Kangma	28 34	89 39
Kangra La	28 6	88 42
Karo La	28 53	90 6
Khāmbā dzong	28 17	88 33
Khongbu Valley	27 40	89
Lachen R.	27 50	88 35
Lachung R.	27 40	88 45
Lamteng	27 44	88 35
Lhāsā	29 38	91 6
Lungma	28 50	89 56
Mangtsa	28 25	89 33
Masongchungdong	27 33	89 9
Me-do	28 5	88 42

	Latitude.	Longitude.
	° ′	° ′
Mekhyi-gunru	28 10	88 33
Nam	29 28	90 55
Nyang Chhu	29	89 30
Pauhanri	27 55	88 53
Pembu La	29 48	91 8
Pemo La	27 42	89 14
Penam dzong	29 9	89 13
Phari	27 43	89 12
Ralung	28 48	90 3
Rong Valley	29 10	90
Salakhang	28 50	89 52
Shigatse	29 18	88 55
Shikar dzong	28 42	87 10
Talung	27 40	89
Tang La	27 51	89 13
Tangu	27 54	88 34
Tengri Nur	30 40	90 30
Tsangpo R.	29 16	
Tūna	27 58	89 16
Tung	27 33	88 40
Utsi	28 20	88 32
Yamdok Tso	28 50	90 35
Yaru R.	28 15	88 20
Yung La	29 4	89 47

THE OCCURRENCE OF BAUXITE IN INDIA. BY T. H. HOLLAND, F.R.S., *Director, Geological Survey of India.*

IN the Review of the Mineral Production, published in the first part of the present volume, attention is called to the fact that India possesses a possible asset of value in the deposits of laterite which cover considerable areas in the Peninsula and Burma.[1] The object of this note is to announce, as the result of the exploratory work which has been in progress during the past year, the determination in India of a number of "prospecting propositions" in aluminous deposits, similar to those known in Europe and America as bauxites, and now being developed as the only practicable source for aluminium, and as one of the materials employed for the manufacture of aluminic salts.

Reference to the literature quoted in the General Report of the Geological Survey published in this part of the *Records* (*supra*, pp. 141, 142) will give an idea of the interesting scientific problems opened up by the investigation into the origin and nature of laterite, and the solution of these will be helped materially by the economic development of the deposits, which appear to come within the category of marketable aluminous ores. The actual prospecting work comes properly within the sphere of private enterprise, but those who wish to undertake the problem of testing the economic value of the deposits mentioned below may find the information we have collected to be of material assistance, though it should be understood that, in an industry which has developed so rapidly as has the manufacture of aluminium and the processes for extracting alumina from bauxites, any scheme of operations employed as a means for estimating economic probabilities is likely to be out-of-date almost as soon as it is announced.

In conducting this exploratory work I have assumed that the simple export of aluminous laterites to Europe would not be practicable in the face of the present low values of bauxites, and in view of the fact that discoveries of new occurrences, elsewhere as well as in India, have been made at a rate well beyond the rate of increase in the

[1] *Supra*, p. 95.

demand for alumina. I should consequently regard an occurrence to be a reasonable prospecting proposition only on the understanding that it is possible to manufacture pure calcined alumina in India, either for export as such to the European and American markets, or for utilization in the manufacture of aluminium and aluminic salts in the country. It is necessary, however, to state that some of the deposits which have been sampled contain percentages of alumina so well in excess of the average bauxites on the market, that it may be possible, by calcination on the spot, to turn out a product which can bear the heavy cost of transport to the coast and the charges necessarily added to a heavy sea-freight. This is a question for the prospector to settle, and it is capable of simple solution within a very narrow limit of error.

The analyses given below represent some samples which have been taken from normal deposits of laterite, and others which would ordinarily be described as bauxites. Without discussing the question of nomenclature at this stage, it will perhaps be sufficient to explain that the writer is not disposed to accept bauxite as a separate mineral species, that is, a definite chemical compound with specific physical properties. Its composition, often approaching that expressed by the formula Al_2O_3, $2H_2O$, is the result of an intimate admixture of two minerals, gibbsite, Al_2O_3, $3\ H_2O$, and diaspore, Al_2O_3, H_2O.[1] It is, in fact, a rock composed essentially of these two minerals, with varying amounts of accessory compounds of silica, iron, and other substances. To the trade bauxite is a substance in which there are large quantities of aluminic hydrate, in contradistinction to clay, in which the alumina is combined with silica in a form unsuitable for economic separation by present methods. Some laterites have the essential characters of bauxite; others would not be looked upon in the trade as such. Some of the deposits referred to in this note show more of the characters of ordinary bauxite than those recognised as typical of laterites, and some of them are certainly not laterites in the sense of being the product of weathering processes now in operation in the areas in which they are found: they are possibly, however, laterites of a past geological age. This point will probably be settled by the observations made during the economic development of the deposits, and with the establishment of their history and origin we shall be able to define with

[1] The relations of these two compounds are discussed in my paper "On the constitution, origin, and dehydration of Laterite." *Geol. Mag.*, decade IV, vol. X. pp. 59 to 69, 1903.

more precision the meanings and limitations of the terms laterite and bauxite. For the present we regard the former as the wider term, and say that some laterites are in all essentials bauxites.

In estimating the value of the analyses given below it should be kept in mind that the mineral diaspore has a theoretical composition of

Alumina, 85·0; water, 15·0, per cent.

whilst the higher hydrate, gibbsite, is composed of—

Alumina, 65·4; water, 34·6, per cent.

Bauxite, being essentially a mixture of these two, must contain, therefore, less than 85 per cent. of alumina, and it generally contains very much less on account of a partial replacement of the alumina by the isomorphous compound ferric oxide, and by the mechanical admixture of clay, quartz, and other impurities.

A large number of analyses of bauxites on the market will be found quoted in the bibliography given at the end of this note. For those who wish to have a rough mental idea of the composition of a marketable bauxite, it will be sufficient to indicate the very wide limits of variation which occur.

For French bauxites the recorded analyses show alumina varying from 30·3 to 76·9 per cent., and ferric oxide from 0·10 to 48·8. An average sample of Georgia bauxite is given by A. E. Hunt[1] as follows:—

Silica	3
Ferric oxide	1·5
Titania	4·50
Alumina	58·67
Water	32·33
	100·00

A series of 21 analyses of Alabama bauxites quoted by H. Mc Calley[2] shows variations in alumina from 39·44 to 62 per cent., ferric oxide from under 1 to 22·6 per cent., silica from 0·40 to 37·87 per cent., and water from 12·8 to 38·2 per cent. The Arkansas bauxites are returned as varying in alumina percentage between 44·81 and 62·05. The Irish bauxites show similar variations in analyses of individual specimens, but with, in general, a lower percentage of free alumina.

[1] *Trans. Amer. Inst. Min. Eng.*, XXIV, 1895, 858.
[2] *Min. Industry* for 1893, p. 64.

The following partial analyses represent the best samples of Indian bauxites which have so far been tested :—

Laterites (Bauxites) in the Madras Presidency.

	A	B	C	D	E	F	G
Alumina, Al_2O_3 .	62·80	64·34	31·37	45·77	63·14	38·28	35·38
Ferric oxide, Fe_2O_3 .	0·44		40·18	9·30		37·88	34·37
Water, H_2O . .	33·74	31·58	24·18	28·30	16·81	20·70	19·60
Silica, SiO_2 . .	2·78	4·68	2·16	14·58	19·32	3·14	10·75
Titania, TiO_2 . .	0·04	0·95	2·01	0·52	—	—	0·10
Lime, CaO . .	0·20	—	—	—	—	—	0·40
Magnesia, MgO .	0·03	—	—	1·32	—	—	—
TOTAL .	100·03	101·55	99·90	99·79	99·27	100·00	100·00

A. Specimen collected and analysed by H. Warth (*Min. Mag.*, XIII, 1902, 172). Specific gravity, 2·42 ; cream-coloured nodules forming a layer about 1 foot in thickness, mixed with various forms of clay and decomposition products of the charnockite series. The specimen analysed is practically pure gibbsite, $Al_2O_3\ 3H_2O$, soluble in boiling sulphuric acid and in boiling caustic soda solution. Locality, Kodaikanal, Palni hills.

B. Laterite collected by H. H. Hayden, at Fort Hamilton, 12 miles south of Kodaikanal, Palni hills. The analysis does not show the ferric oxide distinct from the alumina, but the former is present in small quantities only. Geological Survey collection, No. J. 574.

C. Laterite collected by H. H. Hayden near the Golf Club Pavilion, Ootacamund, Nilgiri hills. In making the analysis the silica and titania were not completely separated from one another.

D. Collected by H. H. Hayden, 4 miles south of Kodaikanal, Palni hills. The analysis does not distinguish the combined silica which would hold a portion of the alumina from that present as quartz, which would not interfere with extraction of the alumina. Geological Survey collection, No. J. 575.

E. Laterite collected by C. S. Middlemiss, from hill south-west of Girliguma in the Vizagapatam hill-tracts. The analysis does not

separate the ferric oxide which is present in quantity sufficient to give the specimen a rusty colour. Geological Survey collection, No. 15,704.

F and G. Specimens from the Nilgiri hills, obtained through the Superintendent of the Government Museum, Madras, and analysed by H. and F. J. Warth (*Geol. Mag.*, dec. IV, vol. X, 1903, 155). Of the silica in specimen G, 10·52 is returned as quartz. Specific gravity of F = 3·09, of G, 3·07.

Laterites (*Bauxites*) *in the Central Provinces and Central India.*

	H	I	J	K	L	M
Al_2O_3	65·48	52·67	51·62	54·20	67·88	57·50
Fe_2O_3	3·77	7·04	5·51	4·02	4·09	6·53
H_2O	19·38	29·83	30·72	27 93	26·47	26·94
SiO_2	0·38	1·26	0·05	1·55	0·93	2·35
TiO_2	11·61	7·51	7·51	12·21	1·04	6·61
CaO	...	1·75	5·25	...	0·36	0·15
MgO	trace	trace		...		*nil*
TOTAL	100·62	100·06	100·66	99·91	100·77	100·08

H. Light buff-coloured, coarsely pisolitic form, collected by P. C. Dutt, near Katni, Jubbulpore district. Analysis by T. R. Blyth. Of the water returned as 19·38 per cent., 1·06 was moisture lost at 100°C., and the rest, 18·32 per cent., was combined.

I. Brown, pisolitic material, collected at Katni, Jubbulpore district, by T. H. Holland. Referred to by F. R. Mallet as aluminous laterite (*Rec. Geol. Surv. Ind.*, XVI, 1883, 113). In large deposits associated with **H** and used commonly for road-metal and ballast on the railway. Analysis by T. R. Blyth. Corresponding specimens collected by F. R. Mallet (Nos. F. 155—157) analysed by H. and F. J. Warth, gave Al_2O_3, 54·80, and TiO_2, 0·38 (*Geol. Mag.*, 1903, 155).

J. Yellowish, pisolitic rock, collected by L. L. Fermor, from a hill 1¼ mile, E-N-E. of Rupjhar, Baihir tahsil, Balaghat district. Analysis by T. R. Blyth. The water, returned as 30·72 per cent., includes 0·74 moisture lost at 100° C.

K. Brownish-yellow, pisolitic rock, collected by H. H. Hayden, from west side of scarp 2 miles north of Samnapur, Baihir tahsil, Balaghat district. Analysis by H. H. Hayden and T. R. Blyth.

L. Mottled laterite collected by T. L. Walker on Korlapat hill, Kalahandi State. Geological Museum No. 15,215. Analysis by H. and F. J. Warth (*Geol. Mag.*, dec. IV, vol. X, 1903, 155). Checked by determination in the Geological Survey laboratory: SiO_2, 0·92; H_2O, 26·82; Al_2O_3 and Fe_2O_3, 72·63.

Laterites (bauxites), with the same characters as those proved to be aluminous by analysis, occur also in the Baihir tahsil of Balaghat at—

(1) Laughar, near the P. W. D. bungalow on the road from Balaghat to Baihir.
(2) A low mound, three-quarters of a mile long, near Gudma.
(3) Forming low hills, 1½ miles north-east of Samnapur.
(4) High hills, due north of Samnapur.
(5) A hill, 4 miles west of Sihora, Jubbulpore district.

M. Laterite collected by C. A. Hacket, from Bijeeragogarh, Marwara, Central Provinces. Analysis by H. and F. J. Warth (*Geol. Mag.*, 1903, 155). Specific gravity, 2·39. Geological Survey No. 32,111.

Laterites (Bauxites) in Bengal and Bombay.

	N	P	R	S
Al_2O_3	64·64	58·23	50·46	43·83
Fe_2O_3	6·21	5·48	23·41	26·61
H_2O	24·00	28·10	24·99	23·88
SiO_2	1·79	2·01	0·72	0·37
TiO_2	3·30	6·49	0·42	4·45
CaO	0·04	0·45	—	0·86
MgO	0·02	—	—	
TOTAL	100·00	100·76	100·00	100·00

N. Pisolitic laterite collected by V. Ball, Neturhat, Palamau, Chota Nagpur. Analysis by H. and F. J. Warth (*Geol. Mag.*, 1903, 155). Specific gravity, 2·59. Geological Survey collection No. 772.

P. Earthy laterite, Sarguja State, Chota Nagpur. Analysis by

H. and F. J. Warth (*Geol. Mag.*, 1903, 155). Geological Survey collection No. 1,295.

R. Laterite said to have been obtained from Mahabaleshwar, and consequently resting on the Deccan Trap. Analysis by H. and F. J. Warth (*Geol. Mag.*, 1903, 155).

S. Laterite interstratified with the nummulitic rocks, Turkesar, Satara. Analysis by H. and F. J. Warth (*Geol. Mag.*, 1903, 155). Geological Survey collection No. 1,309.

An interesting feature in the analyses is the high return so frequently made for titanic acid, and the same circumstance is noticed in connection with foreign bauxites, especially those of America, where a large number of analyses have been made in the deposits being developed in Georgia, Alabama and Arkansas. The very high percentages of 11·61 for the Katni sample (H) and 12·21 for Samnapur sample (K) indicate the probable existence of some unfamiliar substance being precipitated with the titania. This material is now under investigation, but has so far eluded detection by the ordinary tests applied to well known substances in the same class. Dr. R. S. Bayer, whose process for the extraction of alumina by digestion of bauxite in caustic soda has been largely employed, studied the insoluble residues of bauxites, and amongst a great variety of the rarer elements, obtained reactions for some strange substance which he considered to be a new element.[1]

It is not the intention of this paper to discuss methods for the profitable exploitation of Indian bauxites; but as a warning to those who may be in haste to take out prospecting licenses, and as a help to the usually smaller number by whom mineral exploitation is not classified with the games of pure chance, it may be desirable to indicate some of the obstacles which will possibly be met between the prospecting and the mining stages.

In the first place, it is practically certain that, with present prices ruling a limited market, no bauxite will be found in quantity of the quality which could cover the costs of simple export to existing markets The prices quoted in the New York market up to the end of last month for wholesale lots of Georgia and Alabama bauxites varied between 21 and 22 shillings per ton of the first-grade qualities. The capacity of the market is indicated by the following table, showing the World's production during the years 1898–1902. Although there has

[1] *Chemical News*, LXXI, 1895, 128.

been a considerable percentage of increase in the five years, the total consumption is small compared to the quantity of material in sight in India.

Production of Bauxite in Metric Tons.

YEAR.	France.	United States.	United Kingdom.	TOTAL.
1898 . .	36,723	27,220	12,600	**76,543**
1899 . .	48,215	37,402	8,137	**93,754**
1500 . .	58,530	23,556	5,873	**87,959**
1901 . .	76,620	19,207	10,357	**106,184**
1902 . .	96,900	29,690	9,192	**135,782**

In the second place, it is not always easy to distinguish the valuable aluminous bauxites from the associated varieties of clay, and the considerable variations from one part of the deposit to another will involve an additional expense in supervision of the product before despatch to the market.

Finally, the analyses given above are insufficient in themselves to indicate the suitability of the ores for the separation of pure alumina. Bauxites with low percentages of total alumina sometimes lend themselves to the present processes for extracting the oxide better than those shown by bulk analysis to be rich. Apart from the fact that some of the alumina may be in combination with silica, the lower hydrate, diaspore, $Al_2O_3\ H_2O$, which raises the alumina percentage, is far less soluble than the less aluminous form, gibbsite, $Al_2O_3\ 3H_2O$. The precise determination of the chemical constitution will thus form the first stage in the prospecting operations which are warranted by a satisfactory result for chemical composition.

To what extent the most recently patented processes have reduced the cost of extracting pure alumina from bauxites is unknown; but it may be assumed that reticence on the part of the few companies engaged in the manufacture of aluminium is not due to the narrowness of the profitable margin on which they are able, without appeal to the public, to extend their scale of operations. It is at any rate

certain that one of the large items in the total cost of a pound of aluminium is the cost due to the preliminary manufacture of the pure oxide by such processes as extraction by sulphuric acid, heating with carbonate of soda, or digestion with caustic soda.

The value of the alumina will largely determine the question as to whether the deposits are worth working simply for the preparation of the pure oxide, or whether it will be necessary to combine this process of extraction with the manufacture of the metal.

For a practical test of the first proposal the apparatus is comparatively inexpensive, but the installation of plant necessary for the manufacture of the metal should not be undertaken without counting the cost. The comparatively high price of the purified alumina has recently forced attention to processes for the preparation of the oxide at sites near the deposits of bauxite: this is being attempted in the United States, whilst the oxide used at Foyers in Inverness is prepared at Larne from the Antrim bauxites.

The manufacture of the purified alumina from bauxite is of course a purely chemical process, involving no unusual expenditure of energy and, in the case of the alkali processes, only small loss of chemicals, as the alkali employed to make the sodic aluminate is recovered during the separation of the alumina. For the manufacture of aluminium electric power works will be necessary, and the purpose of this note will end by reminding possible investors that in Bengal coal we have a reserve of energy which can be converted into electricity at a cost probably as low as water power. Besides being the immediate source of the metal, alumina is used in dyeing and as a base for the manufacture of aluminic salts.

Besides general works on chemistry and metallurgy, the following publications contain information of special value to those who wish to follow up this subject:—

J. W. Richards. Aluminium, its history, occurrences, properties, metallurgy, and applications. 3rd Edition, Philadelphia and London, 1896.

The Mineral Industry, published annually (New York), with special articles on *aluminium* by J. W. Richards (1893), J. B. C. Kershaw (1901 and 1902); on *alum* by J. Enequist (1894); and on *bauxite* by H. McCalley (1893) and J. Struthers (1902).

F. Laur. The Bauxites: a study of a new mineralogical family. *Trans. Amer. Inst. Min. Eng.*, XXIV, 1895, 234—242, 855—861.

C. W. Hayes. The geological relations of the Southern Appalachian bauxite deposits. *Amer. Inst. Min. Eng.*, XXIV, 243—254.

C. W. Hayes. The Arkansas bauxite deposits. *21st Ann. Report, U. S. Geol. Surv.*, 1899—1900, pp. 435—472.

E. Ristori. Aluminium. *Encycl. Britannica*, vol. XXV, 1902, 339.

T. L. Watson. The Georgia bauxite deposits; their chemical constitution and genesis. *Amer. Geologist*, vol. XXVIII, 1901, 25.

MISCELLANEOUS NOTES.

Imports and Exports of Mineral Products during 1904.

IMPORTS.

THE returns for sea-borne, foreign trade for the calendar year 1904 include figures of considerable value to those interested in the mineral industries of India. The following table shows the values recorded for imported minerals and products obtained directly from minerals, exclusive of hardware, cutlery, plated ware, machinery, millwork, railway plant, glass, earthenware and plate of gold and silver.

Imports of Minerals and Products directly obtained from Minerals during 1904

(including Government Stores).

	1904.	*Average for the three years 1901-1903.*
	£	£
Salt	471,034	*451,766*
Metals: Brass	69,932	*66,084*
Copper	1,751,744	*1,090,843*
German silver	127,563	*127,614*
Iron	2,831,493	*2,244,908*
Steel	1,799,018	*1,517,969*
Lead	129,319	*136,444*
Quicksilver	27,472	*28,269*
Tin	258,528	*187,740*
Zinc or spelter	110,891	*87,989*
Unenumerated	81,244	*71,651*
Total of metals	7,187,204	*5,559,511*
Carried over	7,658,238	*6,011,277*

	1904.	*Average for the three years 1901-1903.*
	£	£
Brought forward .	7,658,238	*6,011,277*
Inorganic chemicals	394,982	*377,497*
Mineral oils and paraffin . . .	2,207,995	*2,456,875*
Coal, coke, and patent fuel . . .	325,613	*302,314*
Precious stones and pearls, unset . .	589,679	*835,319*
Stone and marble	17,877	*19,520*
Other building materials	226,428	*155,450*
TOTAL .	11,420,812	10,158,252

It will be noticed with regard to these products, which are nearly all of a kind that might be obtained directly from known minerals in the country, that there has been a very substantial increase in the total value of the imports, the total for the year 1904 representing an increase in value by over 1¼ million sterling, or 12·43 per cent. compared with the average total for the preceding three years, 1901 to 1903.

The two groups of products which have principally affected the totals are metals, of which there has been an increased import to the value of £1,627,693, and mineral oils, of which there has been a decrease in value, to the extent of £248,880. There is a satisfactory deduction to be drawn from both these results: the increase in the imports of metals indicates the approach of the necessary conditions of market required for the profitable exploitation of the large deposits of ore known in the country, whilst the decrease in the imports of mineral oils shows the development of our own oil-fields.

Imports of Metals.

Amongst the metals, the remarkable increase in the demand for foreign copper, rising from an average annual value of one million to 1¼ million sterling, is perhaps the feature of most interest in view of the fact that, amongst metallic ores in India, those of copper are, next to iron, the most conspicuous examples of neglected natural resources. The figures for iron and steel only partially indicate the increased requirements of the country, as there has been an increase also in the imports

of materials made of iron and steel. The imports of machinery and millwork in 1904 were valued at £2,925,260 against an annual average for the preceding three years of £2,142,541, whilst the cost of railway plant and rolling stock imported during 1904 was £3,547,556 against an annual average for the preceding three years of £3,507,979.

A feature of serious importance in connection with the purchases of steel is the fact that only two-fifths of the private imports come from the United Kingdom.

EXPORTS.

The exports of mineral products from India make a small show beside the imports. The values returned for borax, coal, jadestone, manganese-ore, mica, paraffin and petroleum rubies, and saltpetre make a total of less than £900,000, whilst the gold raised in Mysore and the Nizam's Dominions during 1904 must have been worth over £2,300,000, as the output in crude ounces was 623,688, being an increase on the production for 1903 by 23,628, ounces.

Borax and Saltpetre.

The borax trade, which has been declining against the cheap supplies of Europe and America, showed an export in 1904 of 4,246 cwt., valued at £5,419, against an annual average for the three preceding years of 5,385 cwt., valued at £7,898. The saltpetre trade showed no definite variation in any direction; there has been a slight increase, during the past year, in the exports by sea, which amounted to 390,970 cwt., valued at £266,349, against an annual average for the years 1901—1903 of 377,536 cwt., valued at £359,420.

Coal.

The slight increase in the imports of foreign coal has been more than counterbalanced by an increase in the exports from India, due largely to an improved market at Colombo. The quantity exported during 1904 amounted to 602,810 tons, against an average of 486,641 tons for the preceding three years. The return for the past year, though a small amount compared to the whole trade, and though still a small contribution to the total requirements of Singapore, is the highest recorded export of Indian coal.

Mica and Jadeite.

The exports of mica have not definitely changed. The annual average value of the mica exported during the years 1901—1903 was £83,952, which is very near the value, £83,183, returned for the mica exported during 1904. The "jadestone" exported from Burma *vid* Rangoon represents only a part of the total, as considerable quantities of jadeite are sent overland from Upper Burma to China. The quantity of the mineral sent out through Rangoon in 1904 was 2,869 cwt., valued at £43,946, against the average annual quantity of 3,576 cwt., valued at £43,359, for the three years 1901—1903.

Manganese-ore.

The preliminary returns for 1904 show an export of 154,880 tons of manganese-ore against an average of 147,950 tons for the three preceding years.

Petroleum.

An interesting feature is the fact that, besides a growing sale in India, there has been a rapid increase in the export of our mineral oil, as shown by the following figures :—

Exports of Indian Mineral Oils.

YEAR.	Quantity.	Value.
	Gallons.	£
1901	21,305	936
1902	44,002	1,186
1903	747,834	25,037
1904	4,014,077	128,030

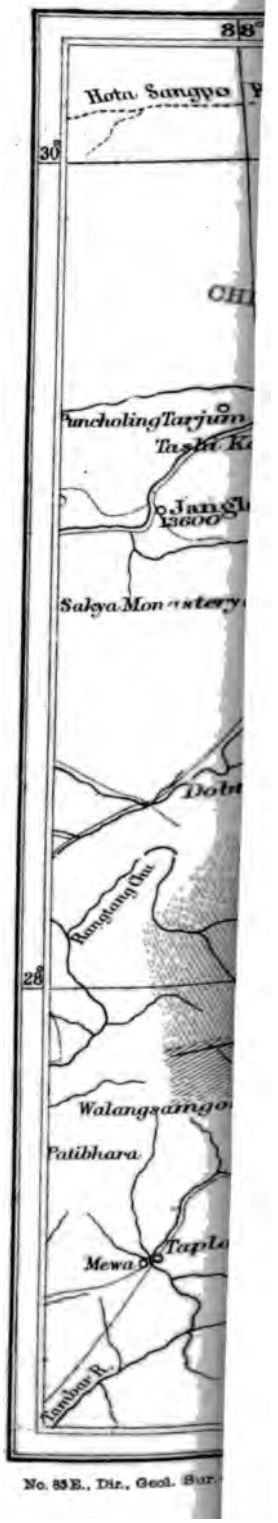
The oil exported to the Straits comes into competition with that from the Dutch East Indies, which has also been assisting to replace Russian kerosene in the Indian market. The import of Russian kerosene has dropped from 90,119,318 gallons in 1901 to 42,256,738 gallons in 1904, whilst that from America, consisting largely of the better grades, has maintained a fairly steady position near $7\frac{1}{2}$ million gallons. The remarkable rise in the imports of oil from the Dutch East Indies, from half a million gallons in 1901 to over 20 millions in 1904, has taken place chiefly during the past year. It is thus evident that the main competitor with Burma and Assam for the Indian market is now the south-eastern extension of the same oil-bearing Tertiary rocks cropping up in the Dutch East Indies.

The exports of paraffin wax show no signs of expansion so far. In 1901 the wax exported amounted to 41,057 cwt., valued at £48,721, but after the rise to 65,041 cwt., in 1902, the trade fell back to 43,206 cwt. in 1903 and to 42,940 cwt., valued at £58,018, in 1904.

[T. H. HOLLAND.]

G. I. C. P. O.—No. 853 D. G. Survey—14-4-05.—650—J. J. M.

H. H. Hayden.



No. 83E., Dir., Geol. Sur.

Part 3.—Note on the progress of the gold industry in Wynaad, Nilgiri district. Notes on the representatives of the Upper Gondwana series in Trichinopoly and Nellore-Cuddapa districts. Sesamoides from Sarawak.

Part 4.—On the geographical distribution of fossil organisms in India. Submerged forest on Bombay Island.

VOL. XII, 1876.

Part 1.—Annual report for 1876. Geology of Kashmir (third notice). Further notices of Siwalik mammalia. Notes on some Siwalik birds. Notes of a tour through Hangrang and Spiti. On a recent coal eruption in Ramri island (Arakan). On Dicynodon, with Rhinosuchus, from near Nagpur, Central Provinces. Palæontological notes from the Satpura coal-basin. Statistics of coal importations into India.

Part 2.—On the Mishpani coal-field. On Pyroxenite with Palæotriakis occurring at Gunalpur, Jabalpur district. A geological reconnaissance from the Indus at Kushalgarh to the Kurram at Thal on the Afghan frontier. Further notes on the geology of the Upper Punjab.

Part 3.—On the geological features of the northern part of Madura district, the Pudukota State, and the southern parts of the Tanjore and Trichinopoly districts included within the limits of sheet No. 66 of the Indian Atlas. Rough notes on the cretaceous fossils from Trichinopoly district, collected in 1877-78. Notes on the genus Sphenopteridium and other Rajmahal ferns, with reference to the Indian form Thinnfeldia Speciosa, Royle (Sphenopteris Feistmantelii, Oldh.). On Mysorite and Alexandrite from the Nellore district. On corundum from the Khasi Hills. On the Jogi neighbourhood and old mines on the Narbudda.

Part 4.—On the 'Attock Slates' and their probable geological position. On a purplish lime of an undescribed tortoise from the Upper Siwaliks near Nila in the Potwar, Punjab. Sketch of the geology of North Arcot district. On the continuation of the road section from Murree to Abbottabad.

VOL. XIII, 1880.

Part 1.—Annual report for 1879. Additional notes on the geology of the Upper Godavari basin in the neighbourhood of Sironcha. Geology of Cudda and neighbouring districts, being fourth notice of geology of Cuddapah and neighbouring territories. Track of fossil fishes from Kutch Island and the Punjab. Note on the fossil genera Nöggerathia, Sillig., Noggerathiopsis, Feist., and Rhiptozamites, Schenk, in palæozoic and secondary rocks of Europe, Asia, and Australia. Notes on fossil plants from Kattywar, Shâh Budin and Girgaish. On volcanic foci of eruption in the Konkan.

Part 2.—Geological notes. Palæontological notes on the lower trias of the Himalayas. On the artesian wells at Pondicherry, and the possibility of finding such sources of water-supply at Madras.

Part 3.—The Kumaun lakes. On the discovery of a reef of palæolithic type in the Punjab. Palæontological notes from the Karharbari and South Rewah coal-fields. Further notes on the correlation of the Gondwanas there with other flexa. Additional note on the artesian wells at Pondicherry. Coal in Rajputana. Record of gas and mud eruptions on the Arakan coast on 12th March 1879 and 10 June 1879.

Part 4.—On some glaciations deposits of the Northern Punjab, and the evidence they afford of an extreme climate during a portion of that period. Useful minerals of the Aravali region. Further notes on the correlation of the Gondwana flora with that of the Australian coal-bearing system. Note on reh or alkali soils and saline well waters. The fossils of Upper India. Note on the Natal Tal landslip, 18th September 1880.

VOL. XIV, 1881.

Part 1.—Annual report for 1880. Geology of part of Darjiling, Rajmahal, and neighbouring districts, being fifth notice of the geology of Rajmahal and neighbouring territories. Note on some Siwalik carnivora. The Siwalik group of the Sub-Himalayan region. On the South Rewah Gondwana basin. On the ferruginous beds associated with the basaltic rocks of north-eastern Ulster in relation to Indian laterite. On some Rajmahal plants. Terrestrial waves of the Punjab. Appendix to 'Palæontological notes on the Lower trias of the Himalayas.' On some pleistocene fossils from Perim Island, in the collection of the Bombay Branch of the Royal Asiatic Society.

geology of the Nilgiri region, Central and Eastern India. On a specimen of native antimony obtained at Pulo Obin, near Singapore. On Tinglas from the neighbourhood of Jaggapett, Nizam's district, and on slate carbonate from Karoul, Madras. Note on the section from Dalhousie to Pangi, and the Kuch Pass. On the South Newyk Gondwana basin. Submerged forest on Bombay Island.

VOL. XV, 1874.

Part 1.—Annual report for 1874. Geology of North-west Kashmir and Kishtwar (being parts series of geology of Kashmir and neighbouring territories), on some Cretaceous Lamellibranchs. On some fossils and fossil localities. On geology of Dalhousie, North-west Himalaya. On remains of palm leaves from the Darjiling Metres and Gaisal beds in India. On Infusorine from the Nor-Dooing river, Upper Assam, and on Flustrem from Chota Nagpur. On (1) a copper mine lately opened near Vongyi hill, in the Darjiling district; (2) arsenical pyrites in the same neighbourhood; (3) kaolin at Darjiling (being 3rd appendix to a report on the geology and mineral resources of the Darjiling district and the Western Duars). Analyses of coal and fire-clay from the Makum coal-field, Upper Assam. Experiments on the coal of Pind Dadan Khan, Salt-range, with reference to the production of gas, made April 20th, 1871. Report on the proceedings and result of the International Geological Congress of Bologna.

Part 2.—General sketch of the geology of the Travancore State. The Warkali beds and reported associated deposits at Quilon, in Travancore. Note on some fossils and Mollusca fossils. On the Coal-bearing rocks of the valleys of the Upper Son and the Mand rivers in Western Chota Nagpur. On the Deotholi river coal-field in Chhindwara district, Central Provinces. On borings for coal at Dipsety, British Burma. On sculptures recently discovered in the North-west Himalaya. Relics of a mastodon-like from one of the ancient volcanoes in Cheshire.

Part 3.—Note on the coal of Mach (Mash) in the Bolan Pass, and of Shawl or Shorigh on the Harnai route between Sibi and Quetta. New forms observed in spirits of sulphite from the Western Ghats, Bombay. On the Deps of Dissang and Mash in the North-western Himalayas. Further note on the connexion between the Hazara and the Kashmir series. On the Umaria coal-field (South Rewah Gondwana basin). The Daranggiri coal-field, Garo Hills, Assam. On the outcrops of coal in the Myanoung division of the Henzada district.

Part 4.—On a traverse across some gold-fields of Mysore. Record of borings for coal at Beddadanol, Godavari district, in 1874. Note on the supposed occurrence of coal on the Kistna.

VOL. XVI, 1875.

Part 1.—Annual report for 1874. On the genus Richthofenia, Kays (Anomia Lawrenciana, Koninck). On the geology of South Travancore. On the geology of Chanda. On the basalts of Bombay.

Part 2.—Synopsis of the fossil vertebrata of India. On the Royal Gavyalis (Gavialis). On a skull of Hippotherium antelopinum. On the fire-clay, coal and other materials for the manufacture of iron, in the north-eastern part of the Jabalpur district. On laterite and other manganese ore occurring at Gangpore, Jabalpur district. Further notes on the

Part 4.—Palæontological notes from the Daltonganj and Hutar coal-fields to Chota Nagpur. On the altered basalts of the Dalhousie region in the North-western Himalayas. On the microscopic structure of some Sub-Himalayan rocks of tertiary age. On the geology of Jaunsar and the Lower Himalayas. On a traverse through the Eastern Khasia, Jaintia, and North Cachar Hills. On native lead from Maulmain and almandite from the Andaman Islands. Notice of a fiery eruption from one of the mud volcanoes at Cheduba Island, Arakan. Notes.—Irrigation from wells in the North-Western Provinces and Oudh.

Vol. XVII, 1884.

Part 1.—Annual report for 1883. Considerations on the smooth-water anchorages or mud banks at Narrakal and Alleppy on the Travancore coast. Rough notes on Billa Surgam and other caves in the Kurnool district. On the geology of the Canari and Sihawla pergunas of Chanda. On the occurrence of the genus Lyttonia, Waagen, in the Kuling series of Kashmir.

Part 2.—Notes on the earthquake of 31st December 1881. On the microscopic structure of some Himalayan granites and gneissose granites. Report on the Chuli coal exploration. On the valley-in-valley of certain localities for fossils in the Siwalik beds. On some of the mineral resources of the Andaman Islands in the neighbourhood of Port Blair. The intertrappean beds in the Deccan and the Laramie group in western North America.

Part 3.—On the microscopic structure of some Aravali rocks. Section along the Indus from the Peshawar Valley to the Salt-range. On the selection of sites for borings in the Raigarh-Hingir coal-field (first notice). Note on Ilmenite near Raipore, Central Provinces. The Tampalan mines of Nilchiti, Rhenanese. Notice of a further fiery eruption from the Minbyin mud volcano of Cheduba Island, Arakan. Report on the Langrin coal-field, south-west Khasia Hills. Additional notes on the Umaria coal-field.

Part 4.—On the Geology of part of the Gangamira gorges of British Garhwal. On fragments of slates and schists imbedded in the gneissose granite and granite of the Northwest Himalayas. On the geology of the Takht-i-Sulaiman. On the smooth-water anchorages of the Travancore coast. On auriferous sands of the Subansiri river, Fossil-bearing lignite, and phosphatic rocks at Mauri. Work at the Billa Surgam caves.

Vol. XVIII, 1885.

Part 1.—Annual report for 1884. On the country between the Singareni coal-field and the Kistna river. Geological sketch of the country between the Singareni coal-field and Hyderabad. On coal and limestone in the Dudgoong river, near Golaghat, Assam. Himalayan, as illustrated from Indian formations. Afghan field notes.

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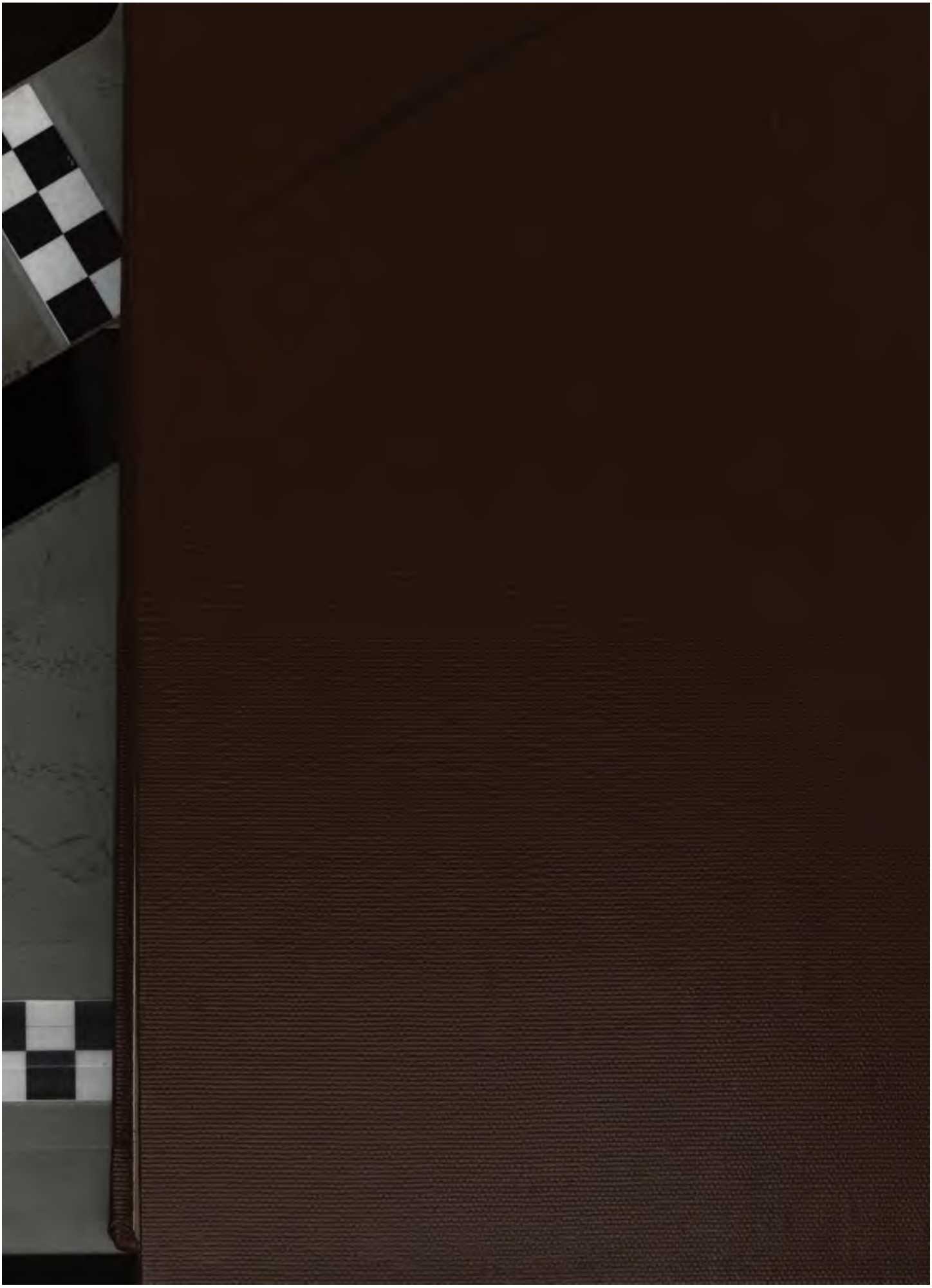
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